Lake Superior Mining Institute

PROCEEDINGS—1908

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PROCEEDINGS

OF THE

Lake Superior Mining Institute

THIRTEENTH ANNUAL MEETING

MESABI RANGE, MINNESOTA

JUNE 24, 25, 26, 27, 1908

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[NOTE. The Secretary is much disappointed in not being able to present in this volume the papers on "Coleraine" and the "Hydro-Electric Plant of the Great Northern Power on St. Louis River." These papers were promised for the annual meeting but were not received up to the tim of closing this volume.]

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TURNER, SCOTT ....326 Franklin Ave., Lansing, Mich.

UREN, WILLIAM J..................................Calumet, Mich.

VALLAT, BENJAMIN W...........................Virginia, Minn.
VAN DYKE, W. D..................................Milwaukee, Wis.
VANDEVENTER, JOSEPH ....Ishpeming, Mich.
VAN EVERA, JOHN R...........................Marquette, Mich.
VAN EVERA, WILLBUR, ...McKinley, Minn.
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VAN ORDEN, F. L.................................Houghton, Mich.
VAN ORDEN, MATHEW ....Houghton, Mich.
VAN VALKENBURG, ALLEN J...................Abbottsford, Wis.
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WAGNER, JOHN M.................................Houghton, Mich.
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WARREN, O. B.......................................Hibbing, Minn.
WARRINER, S. D...............................Wilkesbarre, Pa.
WATSON, CHARLES H. ....Crystal Falls, Mich.
WEBB, FRANCES J ....Eveleth, Minn.
WEARNE, WILLIAM ....Hibbing, Minn.

WEED, LOUIS B. ....Sunrise, Wyoming.
WELDEN, JAMES WALTER, JR.....................Ironwood, Mich.
WELLS, PEARSON ....Ironwood, Mich.
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WESSINGER, HENRY J..............610 Wolvin Bldg., Duluth, Minn.
WEST, WILLIAM J...................................Hibbing, Minn.
WHITBURN, HENRY ....Virginia, Minn.
WHITE, WILLIAM ....Aurora, Minn.
WHITEHEAD, R. G...................................Amasa, Mich.
WHITING, S. B..................................Swampscott, Mass.
WILKINS, WILLIAM ....Ashland, Wis.
WILLIAMS, JAMES H............................Ishpeming, Mich.
WILLIAMS, THOMAS H...................................Ely, Minn.
WILLIAMS, HERBERT H.........................Marquette, Mich.
WILLIAMS, PERCIVAL S..........................Montreal, Wis.
WILLMOTT, ARTHUR B. ....Sault Ste. Marie, Ont.
WINCHELL, HORACE V.....220 Great Northern Bldg., St. Paul, Minn.
WINTER, JOSEPH H..............................Negaunee, Mich.
WITHERBEE, F. S. ....2 Rector St., New York City.
WOODBRIDGE, DWIGHT E...........................Duluth, Minn.
WOODWORTH, G. L..............................Iron River, Mich.
WORDEN, JOHN ....Crystal Falls, Mich.

YOUNG, H. OLIN ....Ishpeming, Mich.
YOUNGS, FRANK W.............................Iron River, Mich.
YOUNGS, GEORGE C...............................Florence, Wis.
YOUNGS, G. W. ....Iron River, Mich.
YUNGBLUTH, A. J...............................Ishpeming, Mich.

DECEASED MEMBERS.

ARMSTRONG, J. F.................................March 3rd, 1898
BENNETT, JAMES H..
BULLOCK, M. C................................January 12, 1899
BAWDEN, JOHN T...1899
BROOKS, T. B..1902

CONRO, ALBERT..............................January 10th, 1901

DANIELS, JOHN ....September 13th, 1898
DICKENSON, W. E................................June 15th, 1899
DOWNING, W. H....................................October, 1906
DUNSTON, THOMAS B..
DUNCAN, JOHN ....June, 1904

GARBERSON, WILLIAM R..........................April 29th, 1908

HOLLEY, S. H. ....July 4th, 1899
HARPER, GEORGE VANCE ....March, 1905
HAYDEN, GEORGE ....July 27th, 1902
HOUGHTON, JACOB ....December 30th, 1903
HINTON, FRANCIS 1896
HOLLAND, JAMES ....September 3rd, 1900
HYDE, WELCOME.............. ....

JEFFERY, WALTER M...........................May 26th, 1906

JOCHIM, JOHN W............................January 17th, 1905

KRUSE, JOHN C...............................October 28th, 1907

LUSTFIELD, A.....................................May 26th, 1904
LYON, JOHN B................................February 13th, 1900

MARR, GEORGE A..................................March, 1905
MITCHELL, SAMUEL............................May 10th, 1908
M'VICHIE, D.......... ....September 14th, 1906

OLIVER, HENRY W...........................February 8th, 1904

PEARCE, H. A..1905
PERSONS, GEORGE R.........................March 26th, 1908

RYAN, EDWARD 1901

SHEPHARD, AMOS ....June 6th, 1905
STANTON, JOHN ....February 23rd, 1906

TREVARTHEN G. C. ....January, 1898
THOMAS, HENRY ....December, 1905

VAN DYKE, JOHN H. 1906

WALLACE, JOHN 1898
WILLIAMS, W. H. 1897
WHITE, PETER..... ....June 6th, 1908
WHITNEY, J. D...1894

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2	Houghton, Mich	March 7-9, 1894	Vol. II
3	Mesabi and Vermilion Ranges	March 6-8, 1895	Vol. III
4	Ishpeming, Mich	August 18-20, 1896	Vol. IV
5	Ironwood, Mich	August 16-18, 1898	Vol. V
6	Iron Mountain, Mich	February 6-8, 1900	Vol. VI
7	Houghton, Mich	March 5-9, 1901	Vol. VII
8	Mesabi and Vermilion Ranges	August 19-21, 1902	Vol. VIII
9	Ishpeming, Mich	August 18-20, 1903	Vol. IX
10	Ironwood, Mich	August 16-18, 1904	Vol. X
11	Iron Mountain, Mich	October 17-19, 1905	Vol. XI.
12	Houghton, Mich	August 8-10, 1906	Vol. XII
13	Mesabi and Vermilion Ranges	June 24-27, 1908	Vol. XIII

Note—No meetings were held in 1897, 1899 and 1907.

RULES OF THE INSTITUTE.

I.

OBJECTS.

The objects of the Lake Superior Mining Institute are to promote the arts and sciences connected with the economical production of the useful minerals and metals in the Lake Superior region, and the welfare of those employed in these industries, by means of meetings of social intercourse, by excursions, and by the reading and discussion of practical and professional papers, and to circulate, by means of publications among its members the information thus obtained.

II.

MEMBERSHIP.

Any person interested in the objects of the Institute is eligible for membership.

Honorary members not exceeding ten in number, may be admitted to all the privileges of regular members except to vote. They must be persons eminent in mining or sciences relating thereto.

III.

ELECTION OF MEMBERS.

Each person desirous of becoming a member shall be proposed by at least three members, approved by the Council, and elected by ballot at a regular meeting (or by ballot at any time conducted through the mail, as the Council may prescribe), upon receiving three-fourths of the votes cast. Application must be acompanied by fee and dues as provided by Section V.

Each person proposed as an honorary member shall be recommended by at least ten members, approved by the Council, and elected by ballot at a regular meeting, (or by ballot at any time conducted through the mail, as the Council may prescribe), on receiving nine-tenths of the votes cast.

IV.

WITHDRAWAL FROM MEMBERSHIP.

Upon the recommendation of the Council, any member may be stricken from the list and denied the privilege of membership, by the vote of three-fourths of the members present at any regular meeting, due notice having been mailed in writing by the Secretary to him.

V.

DUES.

The membership fee shall be five dollars and the annual dues five dollars, and applications for membership must be accompanied by a remittance of ten dollars; five dollars for such membership fee and five dollars for dues for the first year. Honorary members shall not be liable to dues. Any member not in arrears may become a life member by the payment of fifty dollars at one time, and shall not be liable thereafter to annual dues. Any member in arrears may, at the discretion of the Council, be deprived of the receipt of publications or be stricken from the list of members when in arrears six months; Provided, That he may be restored to membership by the Council on the payment of all arrears, or by re-election after an interval of three years.

VI.

OFFICERS.

There shall be a President, five Vice-Presidents, five Managers, a Secretary and a Treasurer, and these Officers shall constitute the Council.

VII.

TERM OF OFFICE.

The President, Secretary and Treasurer shall be elected for one year, and the Vice-Presidents and Managers for two years, except that at the first election two Vice-Presidents and three Managers shall be elected for only one year. No President, Vice-President, or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. The term of office shall continue until the adjournment of the meeting at which their successors are elected.

Vacancies in the Council, whether by death, resignation, or the failure for one year to attend the Council meetings, or to perform the duties of the office, shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; Provided, That such appointment shall not render him ineligible at the next election.

VIII.

DUTIES OF OFFICERS.

All the affairs of the Institute shall be managed by the Council except the selection of the place of holding regular meetings.

The duties of all Officers shall be such as usually pertain to their offices, or may be delegated to them by the Council.

The Council may in its discretion require bonds to be given by the Treasurer, and may allow the Secretary such compensation for his services as they deem proper.

At each annual meeting the Council shall make a report of proceedings to the Institute, together with a financial statement.

Five members of the Council shall constitute a quorum; but the Council may appoint an executive committee, business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary and recorded by him with the minutes.

There shall be a meeting of the Council at every regular meeting of the Institute and at such other times as they determine.

IX.

ELECTION OF OFFICERS.

Any five members not in arrears, may nominate and present to the Secretary over their signatures, at least thirty days before the annual meeting, the names of such candidates as they may select for offices falling under the rules. The Council, or a committee thereof duly authorized for the purpose, may also make similar nominations. The assent of the nominees shall have been secured in all cases.

No less than two weeks prior to the annual meeting, the Secretary shall mail to all members not in arrears a list of all nominations made and the number of officers to be voted for in the form of a letter ballot. Each member may vote either by striking from or adding to the names upon the list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing the ballot with his name, and either mailing it to the Secretary, or presenting it in person at the annual meeting.

In case nominations are not made thirty days prior to the date of the annual meeting for all the offices becoming vacant under the rules, nominations for such offices may be made at the said meeting by five members, not in arrears, and an election held by a written or printed ballot.

The ballots in either case shall be received and examined by three tellers appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected. The ballot shall be destroyed, and a list of the elected officers, certified by the tellers, snall be preserved by the Secretary.

X.

MEETINGS.

The annual meeting of the Institute shall be held at such time as may be designated by the Council. The Institute may at a regular meeting select the place for holding the next regular meeting. If no place is selected by the Institute it shall be done by the Council.

Special meetings may be called whenever the Council may see fit; and the Secretary shall call a special meeting at the written request of twenty or more members. No other business shall be transacted at a special meeting than that for which it was called.

Notices of all meetings shall be mailed to all members at least thirty days in advance, with a statement of the business to be transacted, papers to be read, topics for discussion and excursions proposed.

No vote shall be taken at any meeting on any question not pertaining to the business of conducting the Institute.

Every question that shall properly come before any meeting of the Institute, shall be decided, unless otherwise provided for in these rules, by the votes of a majority of the members then present.

Any member may introduce a stranger to any regular meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

XI.

PAPERS AND PUBLICATIONS.

Any member may read a paper at any regular meeting of the Institute, provided the same shall have been submitted to and approved by the Council, or a committee duly authorized by it for that purpose prior to such meeting. All papers shall become the property of the Institute on their acceptance, and, with the discussion thereon, shall subsequently be published for distribution. The number, form and distribution of all publications shall be under the control of the Council.

The Institute is not, as a body, responsible for the statements of facts or opinion advanced in papers or discussions at its meetings, and it is understood, that papers and discussions should not include personalities, or matters relating to politics, or purely to trade.

XII.

AMENDMENTS.

These rules may be amended by a two-thirds vote taken by letter ballot in the same manner as is provided for the election of officers by letter ballot; Provided, That written notice of the proposed amendment shall have been given at a previous meeting.

THE THIRTEENTH ANNUAL MEETING.

The thirteenth annual meeting of the Institute was originally planned for July 24th to 27th, 1907, and all arrangements were made accordingly. A few days prior to the meeting, however, the labor troubles, which then existed at certain points in the district assumed a somewhat threatening aspect, causing some of the mines to close down and it was decided to postpone the meeting and arrangements were cancelled. While the situation very soon changed and work on the docks and at the mines was again resumed, it was nevertheless still thought advisable by the committee in charge to defer the meeting until 1908. In May of this year, Mr. T. F. Cole, president of the Institute and the members in the Minnesota District, again planned for the meeting and it was decided to hold the Thirteenth Annual Meeting June 24th to 27th, 1908.

Much credit is due to the different committees for their efforts in the arrangement of the trip. The train schedule was carried out as planned without loss of time and for the greatest comfort of the party. The meeting will be long remembered and is spoken of as the best in the history of the Institute. The pleasant weather throughout the trip added greatly to the comfort and pleasure of the occasion.

The programme, prepared by Mr. D. E. Woodbridge, and issued by the Committee on Arrangements, covering the trip to the ranges contains much valuable information about the mines, which will be of general interest to the members and the same is published herewith. Only such parts as the analysis of ore from the various Lake Superior District, which are changeable, are omitted.

Following is the list of the different committees:

Arrangement Committee.

WILLIAM J. OLCOTT, Chairman.

William C. Agnew
Pentecost Mitchell,
C. T. Fairbairn,
Dwight E. Woodbridge.
Charles Trezona,
Joseph Sellwood,
W. W. Walker,

Transportation Committee.

W. A. McGONAGLE, Chairman.

F. E. House,
D. M. Philbin,
Thomas Owens,
J. W. Kreitter.

Entertainment Committee.

JOHN H. McLEAN, Chairman.

J. S. Lutes,
Chas. A. Duncan,
G. G. Hartley,
Wm. J. West.

ITINERARY TO THE MINNESOTA IRON RANGES, LOCAL EXCURSIONS, ETC.

The headquarters of the Institute and bureau of information will be at the Spalding Hotel. On arrival, members and their guests will please register at headquarters, receive assignments of accommodations for trip to ranges, etc. On account of both state and interstate laws regulating railroad transportation, it will be necessary for all those participating in this trip to pay the regular railway fare of two cents per mile, excepting such as have, under the law, free transportation on these Minnesota roads. Eight meals will be served in dining cars en route, and for these tickets will be provided, to be bought by members and guests at about cost per meal. Such tickets should be secured prior to departure from Duluth.

Wednesday, June Twenty-fourth.

No special program has been arranged for Wednesday. For the accommodation of such members as may be in Duluth in time to take advantage of it, the privilege of the various clubs of the city has been offered. These include the Kitchi Gammi, Commercial, Northland Country, Duluth Boat and Duluth Yacht clubs. All these clubs have cafes. The golf links are at the Northland Country club, and sail boats or launches may be engaged at the Boat or Yacht club. Tickets to the various clubs may be had on application.

During Wednesday and Saturday, time not otherwise occupied may be profitably spent in an inspection of various industries in and near the city. The transformer station of the Great Northern Power Co., at 15th Avenue West, the Zenith furnace and the ore docks of the Duluth, Missabe & Northern railroad, may all be reached easily by street cars running to West Duluth. The main power station of the Great Northern Power company, at Fond du Lac, can be reached via the Northern Pacific road. In the wholesale districts, on Lake and Fifth avenues, are some of the largest wholesale hardware and other wholesaling and manufacturing houses in the world. On First street and Third Avenue West is the Wolvin building, general offices of the mining companies and railroads of the United States Steel corporation; and the Duluth Board of Trade and the new Y. M. C. A. building, the latter representing an investment of more than $225,000, are across the street. The aerial bridge, the only structure of its kind in the United States, and carrying a car on a truss elevated 140 feet, is on Lake avenue. The boulevard drive, running behind and above the city, at an elevation of 480 feet and utilizing for its roadway the glacial beach of Lake Superior, is, with its adjacent and connecting parks, well worth a visit.

There will be an informal smoker and reception for members of the Institute and their guests at the club house of the Northland Country club at 8 o'clock p. m. The club may be reached by Lakeside cars that pass the Spalding Hotel, going east, at 7:40, 8:00 and 8:20 p. m. Returning cars will pass the club at an hour that will be announced.

Sleeping cars for the trip to the ranges will be ready for occupancy at the Union station at 6:30 p. m. Intending passengers may find it convenient to place their baggage aboard the train early, and then go direct to the Country club for the evening.

Thursday, June Twenty-fifth.

Leave Duluth, Union Station......................1:00 a. m.
Arrive Ely ....5:30 a. m.

Visit Chandler, Pioneer, Zenith, Savoy and Sibley mines; at the Pioneer there will be opportunity for a brief trip underground.

These mines are all operated by the Oliver Iron Mining Co., and last year produced a total of 1,582,290 tons. The underground haulage system of the Pioneer, the various steel shafts and shafthouses, and the hoisting plants here are all of more than passing interest. This "Ely trough" has produced, since 1888, 18,631,606 tons of ore.

Leave Ely ....11:00 a. m.
Arrive Soudan ....12:00 noon.

Visit Minnesota mine. This property is operated by the Oliver Iron Mining company, and was what led to the construction of the Duluth & Iron Range railway. Last year it mined a total of 102,977 tons, or 1.24 per cent. of the tonnage of that road. One of the most picturesque scenes to be found in the northwest is the view of Lake Vermilion to be had from the summit of the hill near the mine buildings.

Leave Soudan ....1:00 p. m.
Arrive Biwabik (Mesabi Range)...................2:30 p. m.

Visit Biwabik mine. This property is operated by the Biwabik Mining Co., and was one of the first to ship from the Mesabi range, and was notable in the early days of the district by reason of the boldness of the plans for stripping, the rapid growth of its production and the excellent character of its ore. The yardage of overburden taken from this mine to date is about 4,500,000, and there have been mined to May, 1908, 8,212,967 tons.

Leave Biwabik ....3:00 p. m.
Arrive Eveleth ....3:45 p. m.

Visit Fayal, Adams and Spruce mines. These properties are operated by the Oliver Iron Mining Co., and last year produced as follows: Fayal, 1,878,812 tons; Adams-Spruce, 1,746,970. At these mines the various methods of mining used on the Mesabi may be seen, and from their surface 9,725,000 yards of overburden have been removed. This portion of the Mesabi was developed for the first shipments in 1895.

At Eveleth the trains will be transferred to the Duluth, Missabe & Northern tracks and will

Leave Eveleth ....6:30 p. m.
Arrive Virginia ....7:15 p.m.

There will be a business session of the Institute at the Roosevelt High School hall, Virginia, at 8:15 o'clock this evening.

Friday June Twenty-sixth.

A portion of the morning will be spent in visiting the Oliver Norman, Ohio, Lincoln Franklin, and other mines. The Oliver is a state lease (returning 25 cents per ton to the public schools of the state) operated by the Oliver company; the Ohio is also mined by that company; the Lincoln is operated by the Interstate Iron Co. (Jones & Laughlins Steel Co.), the Franklin group by the Republic Iron & Steel Co., the Commodore by Corrigan, McKinney & Co. The Oliver group is under extensive development and there has been removed from the properties of the group a total of 2,550,000 yards of overburden.

Leave Virginia ....10:00 a. m.
Arrive Mountain Iron..10:45 a. m.

Visit the Mountain Iron mine. This is operated by the Oliver company and has shipped in two consecutive years a total of more than 5,000,000 tons, and in all to this date 16,992,173 tons. It was the first property to be taken by the Carnegie-Oliver coalition of some years ago, and thus, with the Oliver mine, formed the basis of the Oliver Mining Co. Stripping to the total amount of 4,825,000 yards has been taken off this ore body.

Leave Mountain Iron ....11:45 a. m.
Arrive Monroe—Tener mines ....12:45 p. m.

These mines have been opened on a very large and comprehensive scale, and are excellent examples of stripping and milling properties. A total of 3,875,000 yards of earth has been removed in the past three years.

Leave Monroe—Tener mines..1:30 p. m.
Arrive Hibbing ....2:00 p. m.

The remainder of the day will be passed in visits to various mines of the district. Hibbing is almost surrounded by mines, indeed a large portion of the town lies over ore, and the Sellers is now stripping into the town from the east side. The iron bearing formation and deposit here is not far from two miles wide, and very productive, the immediate vicinity containing many hundred million tons. Notable mines here are the Burt, Sellers, Hull, Rust, Mahoning, Morris, Hartley, and others. From the Burt and Hull-Rust 8,400,000 yards of surface have been moved and they have shipped 9,405,000 tons of ore. Mahoning is stripped in such a manner that passenger trains can be taken into and through the mine itself, a somewhat unique fact. This mine is operated by the Mahoning Iron & Steel Co., and the fee is owned by the Great Northern railway, and a total of 3,500,000 yards of overburden has been removed therefrom.

There will be a business session of the Institute at the Hibbing High school at 8:15 p. m.

Saturday, June Twenty-seventh.

Leave Hibbing ....1:00 a. m.
Arrive Coleraine ....6:00 a. m.

This is the scene of the vast operations of the Oliver Iron Mining Co. in the development of sandy ores of the district that can be concentrated into merchantable ores by a washing process, and an experimental washery is in operation on the shores of Trout Lake. The stripping development here is worthy of especial note, not only for its magnitude, both in extent of area and depth of overburden to be moved, but in the labor-saving methods utilized and in the amount of earth removed month by month. Overburden so far removed amounts to 2,475,000 yards, and from the near-by Holman mine 1,600,000 yards. The town of Coleraine is owned by the company and a most successful attempt is being made to build up here a model dwelling place in which there shall be comforts and conveniences, and inducements for the best class of residents to become permanent citizens. Large sums are being spent and able minds are directing matters towards this end.

Leave Coleraine ....12:00 noon.
Arrive Duluth .... 4:00 p.m.

MINNESOTA STEEL COMPANY.

Recently the Minnesota Steel Company has been organized to erect blast furnaces and a steel works and finishing mills at Duluth under the ownership of the United States Steel Corporation. The company has proceeded with its plans, has bought property giving it nearly three miles of deep water frontage on Duluth harbor, and containing some 1,500 acres, has made surveys, has organized a railway company to construct a belt line connecting the works with all lines of railroads running into Duluth and Superior, has bought large property holdings for railway yards and distributing docks, etc., has organized a company for constructing a bridge across the St. Louis river and secured the right to bridge the channel, and is now perfecting the plans for its equipment and surveying the route of its belt lines. Large sums have been set aside for carrying out this important project, and it is probable the works will ultimately be of great magnitude and of the utmost importance to the city and the northwest. It may be said that this is the most ambitious and well-founded plan for the manufacture of steel and its products that has ever been considered for the northwest. Initial construction will include the following: Two 500-ton blast furnaces; 7 60-ton open hearth furnacess; 160 by-product coke ovens; 1 40-inch blooming mill; 1 28 and 1 18-inch finishing mill; 1 combination finishing mill, comprising a continuous 16-inch roughing mill with 11 and 8-inch finishing mills; a pumping plant of 40,000,000 gallons capacity; a power plant of approximately 8,000 kw., and the necessary machine shops, forges, foundries, etc. with a village of about 100 dwellings, all to cost approximately $11,000,000.

GREAT NORTHERN POWER CO.

The Great Northern Power Company is now delivering electric power from its hydro-electric station on the St. Louis river to various industries and public utilities in Duluth and Superior. The present installation consists of three 10,000 h.p. generating units operating under 375 feet of fall and furnishes power for the lighting and street railways of both cities, for pumping the Duluth water supply, for operating the unloading and conveying machinery of coal docks and grain elevators, for electrolytic processes and for driving the motors of various industries. The installation will be increased ultimately to 80,000 horse power and storage reservoirs will be constructed of sufficient capacity to make an ample water supply continuously available at all times and seasons. To insure reliability, continuity and economy of power service, the equipment and construction has been made typical of the highest state of the art.

The power market within a commercial radius of transmission includes Duluth, Superior, St. Paul, Minneapolis, and the Mesabi, Vermilion and Gogebic iron ranges. The extensive use of this power in one or more of these iron ranges is confidently expected in the near future on account of the proximity of this large water power development and the many advantages of electric power for mining work.

ZENITH FURNACE.

This is the property of the Zenith Furnace Company: it includes a stack 79′ 6″, with bosh 16′ 6″ and crucible 11′ 6″; has three Gordon stoves 60′x16 and one lamond 20x85, and has a daily capacity of 225 tons of pig iron. The slag is granulated and sluiced to fill dock space. It has a by-product coke oven plant of 50 Otto-Hoffman by-product ovens. The capacity of these is: Coal coked 350 tons daily; coke produced—250 tons daily; and the daily product includes 400 gallons tar, 10,-000 pounds concentrated ammonia, 20 per cent. N. H. 3, 1,250,000 cubic feet illuminating gas of 18 candle power are produced daily. It has an auxiliary carburetted water gas plant of 2,000,000 cubic feet daily capacity, to supply gas when furnace is idle. The cities of Duluth and Superior have contracted for the daily product of oven gas, for a term of ten years. The docks of the company are fully equipped for handling and storing a large tonnage of coal. Complete dock, 1,200 feet long by 350 feet wide. A slip 150 feet wide is dredged 3,000 feet in length to a depth of 21 feet. Available dockage room on the company's property is extension of completed dock 2,000 feet additional length and 3,000 feet by 500 feet of dock room on the other side of the present dredge slip.

THE IRON RANGES OF MINNESOTA.

There are two distinct producing iron ranges in Minnesota, the Vermilion and Mesabi. In trend they are approximately parallel (E. N. E. and W. S. W.) and about 15 miles apart. On the west both ranges disappear beneath heavy drift and on the east extend into Canada, the so-called Gunflint range near the international boundary being an eastward continuation of the Mesabi formation. This latter range is of no economic importance, however, at present. The recently discovered Cuyuna range has as yet no producing mines.

The first mention of iron bearing formation in this district is by Norwood in 1852, but it was not until 1875 that we have any record of work being done to establish the economic value of the district. In this year Prof. A. H. Chester examined the Mesabi range from Embarrass lake eastward to Birch lake. In the greater portion of the district examined by Prof. Chester the formation is highly magnetic and has never produced bodies of merchantable ore. Shortly after attention was almost wholly diverted from the Mesabi by the discovery of ore on the Vermilion range.

In the early 80's, Mr. Geo. C. Stone having succeeded in interesting Mr. Charlemange Tower in the ore deposists on the Vermilion range near Tower, docks were built at Two Harbors and the Duluth and Iron Range railroad built to Tower. The first shipment of ore was made in 1884. In 1886 the whole property, including mines, railroad, docks and land grant was sold to the Minnesota Iron Company and later, on the organization of the U. S. Steel Corporation, became a part of the holdings of that corporation. The first mine to be developed near Ely, 21 miles east of Tower, was the Chandler, which began shipping in the fall of 1887. Since then the Pioneer, Zenith, Savoy and Sibley have been opened in what is known as the Ely trough. This entire group is controlled by the United States Steel Corporation.

On the Mesabi range ore was discovered in the fall of 1890 near the present Mountain Iron mine by the Messrs. Merritt of Duluth, and in the fall of the following year on the Biwabik property by the same parties. Since these discoveries the development of this range has been phenomenal. By the end of 1893 three railways, the Duluth & Iron Range, Duluth, Missabe & Northern, and Eastern Railway of Minnesota (Great Northern system) connected the mines with ore docks at Two Harbors, Duluth and Superior.

In 1907, ninety mines on the Mesabi range shipped 27,492,949 tons of ore, as against 12,990,708 tons shipped from eighty-three mines on the Gogebic, Marquette and Menominee ranges.

VERMILION RANGE.

The Vermilion range extends from the vicinity of Tower to and beyond the international boundary, crossing into Canada at the eastern end of Hunter's Island. Merchantable bodies of ore have been discovered at but two localities along this extent, at Tower and at Ely, twenty-one miles east.

The iron bearing formation of this range occupies the lowest position geologically of any of the Lake Superior iron formations, being placed by Van Hise and Clements in the Archean as shown from the following succession:

Lower Huronian.	Intrusive. Granites, granite porphyries, dolerites, and lamprophyres.
	Knife Lake slates.
	Agawa formation (iron bearing).
	Ogishke conglomerate.

(Unconformity.)

Archean.	Intrusive granites, granite-porphyries, and some greenstones. Soudan formation (the iron-bearing formation). (Minor unconformity). Ely greenstone, an ellipsoidally parted basic igneous and largely volcanic rock.

The ores of the Vermilion series occur in the Soudan formation (the Agawa iron bearing rocks are not of commercial importance).

At the Minnesota mine the ore is a dense hard hematite occurring in irregular connected and disconnected lense shaped bodies in the jasper, which is intricately infolded in the spheroidal greenstone or green schists, so-called on account of a characteristic spheroidal parting. The strike is about east and west and the dip approximately vertical with a westerly pitch. The underground workings at this mine are some 4,500 feet in extent east and west, and over 1,500 feet in depth. The structure here is probably the most complex in the Lake Superior iron districts. Above the iron bearing formation, geologically, comes the basal conglomerate of the Lower Huronian carrying large boulders and masses of the iron bearing rocks.

The ores at Ely differ from the preceding, mainly in their physical structure, being much more broken and friable. The area in which they lie is a double ended trough about two miles in length east and west and some 1,500 feet in width. The general dip is nearly vertical and the pitch of the ore bodies at the west end of the trough is to the east while the pitch of those at the east end is to the west. The iron formation here, as at the Minnesota mine, lies in a trough of the older spheroidal greenstone, but the folding is not so close. The geological succession is the same as above given. Intrusive masses and dikes of granitic porphyry and basic eruptives cut the whole series.

MESABI RANGE.

The Mesabi range extends continuously from near Grand Rapids on the Mississippi river E. N. E. for a distance of about 90 miles to near Birch lake, where it is covered by the large gabbro flow which forms the base of the Keweenawan series. The same formation (Mesabi) appears again near Gunflint lake on the international boundary and shows as far east as Thunder bay on the north shore of Lake Superior. Between Mesabi station, on the D. & I. R. Ry., and Birch lake the formation consists of alternate thin layers of chert and magnetic ore, but although considerable exploration work has been done, there is no evidence of concentration of ore in workable bodies in this area. Dr. Leith accounts for the change of ore to a magnetite by the action of the heavy flow of gabbro which is here in close proximity to the iron formation. The Gunflint beds are thin alternating layers of chert and hematite. All the workable deposits, at present known, on the Mesabi lie between Mesabi station and Grand Rapids, the greater number being in St. Louis county.

The geological succession as given by Van Hise and Leith is as follows:

Upper Huronian. (Mesabi Series.)	Virginia slate (upper slate formation). Biwabik formation (iron-bearing formation). Pokegama formation (quartzite and quartz-slate formation).
(Unconformity.)	
Lower Huronian.	Granite, intrusive in lower formations. Slate-graywacke-conglomerate formation (equivalent to the Ogishke and Knife lake formations of the Vermilion district).
(Unconformity.)	
Basement Complex of Archean.	Greenstones, including basalts, diorites, diabases, etc., hornblende-schists, and porphyritic granites and rhyolites.

The north edge of the range was easily determined as exposures of the older rocks are fairly numerous; the south edge, or more properly the north edge of the overlying black slates, was determined by drill work entirely, as there are no exposures of this slate.

The iron formation is flat-lying with a slight average dip to the south, although local high dips occur. In this respect it differs from all other districts in the Lake Superior region.

The great bulk of the iron formation is ferruginous chert more or less amphibolitic, calcareous or sideritic and gray, red, yellow, brown, or green with bands or shoots of iron ore. It is analagous to the jaspers of the other iron ranges.

A few thin beds of slate occur in the formation.

It may be said that the ore bodies in general lie with their longer axes in the direction of the trend of the formation, although they are exceedingly irregular in outline. The transition between the rich ore and the taconite (local term for the ferruginous chert of the ore formation) is usually very abrupt, and the original bedding can be plainly distinguished running through the ore. One body of ore is known to have a continuous extension of over two and a half miles and an average width of about one-half miles and to be several hundred feet thick in places. These flat-lying ore bodies vary in thickness from a few feet to over 500 feet, and a large majority occur just beneath the drift, although some have a jasper capping. The surface or overburden varies from practically nothing to some 200 feet, perhaps an average would lie between 60 and 80 feet.

The ores of the Mesabi are red, brown and yellow hematites and limonites, more or less hydrated, and are secondary replacements or enrichments of the jasper. They are supposed to be mainly derived from the silicates of iron, which are abundant in the rocks of the iron formation, and to a less degree from siderite. In physical structure they vary from a fairly compact phase to earthy or powdery phases, and are comparatively high in moisture. At the west end of the range the ores are more or less "sandy," a condition evidently resulting from the decomposition of the cherty layers in the banded iron and chert.

In 1907 Minnesota furnished 55 per cent. of the total iron ore produced in the United States and 68½ per cent. of the Lake Superior output, the total product of the state to the end of the latter year being 177,020,984 tons.

MINING METHODS.

The mining methods employed on the Vermilion range are, at Ely, the caving system, and at Tower, longitudinal back stoping.

On the Mesabi the following methods are used: Open pit steam shovel; open pit milling; open pit milling steam shovel; slicing; square set, and slicing and caving combined.

THE CUYUNA RANGE.

The Cuyuna iron range, which lies in the vicinity of Deerwood, 80 miles west of Duluth, near the Northern Pacific railway, is the most recently discovered in Minnesota. Mr. Cuyler Adams' attention was attracted to magnetic variations in that vicinity a number of years ago, and after detailed magnetic work, he, in 1904, started drilling near Deerwood, with the result that it was demonstrated that an iron formation exists in that vicinity. Since this time considerable drilling has been done, and shafts sunk by Pickands-Mather Company and by the Rogers-Brown Ore Company. No mines have yet been opened on this range.

The surface is rolling, dotted with glacial lakes, and the glacial drift is very heavy, in places a thickness of over 300 feet of this material occurring above the rock formation. There are few rock exposures in the immediate vicinity, practically the only indications of the iron formation being the lines of magnetic attraction mentioned above.

The diamond drilling seems to have proved that the rock succession here, from the base upward, is, 1st, either a quartsite or greenstone; 2nd, a series of iron slates containing the ore in comparatively narrow belts or lenses; 3rd, chlorite slates, and 4th, either drift or cretaceous material. This whole series is apparently cut by greenstones and granite rock.

The rocks are folded, the drilling showing that they have a practically vertical dip. There are several nearly parallel lines of magnetic attraction in this district; whether this represents the same formation brought up by repeated folding, or several different formations has not been determined, though it is probably the former.

RAILROADS.

DULUTH & IRON RANGE RAILROAD.

The Duluth & Iron Range railroad was built from Two Harbors to the Vermilion range at Tower, a distance of 67.6 miles, in 1884, and extended to Ely, 21 miles east of Tower, in 1888. It was built into Duluth in 1886, and branches were extended from its mainline to the Mesabi mines in 1892 and 1893. The original grades on this road are very steep, going north, and in the thirteen miles from Two Harbors to Highland there is a rise of 1150 feet. A new line between these points has been built with an increase of three miles in distance and with maximum grades of 1 per cent.

DULUTH, MISSABE & NORTHERN RAILWAY.

The Duluth, Missabe & Northern railway was constructed from Stony Brook to Mountain Iron, a distance of 48.62 miles, in 1892. The Biwabik branch from Iron Junction to Biwabik, a distance of 15.54 miles, was constructed in 1892. The Superior branch from Wolf to Hibbing, a distance of 16.06 miles, was constructed in 1893. The Duluth extension from Columbia Junction to Duluth, a distance of 29.34 miles, was completed in 1893. The Alborn branch from Coleraine Junction to Coleraine, a distance of 53 miles, was constructed in 1906. The total main line mileage is 242 miles, of which 82 miles from Duluth to Hibbing is double tracked.

The maximum south bound grade against the loads is 0.3 per cent. The maximum north bound grade against the empties is 2.0 per cent., this extending only six miles from the ore docks to the south end of the yard at Proctor. The entire main line with the exception of a small part of the Biwabik branch is laid with 80 pound steel rails. The balance of the tracks are laid with 80 pound and 60 pound steel rails.

Seven miles of the double track between the ore docks and Proctor is rock ballasted; the balance of the road is ballasted with gravel.

The shops and classification yards are at Proctor. The ore docks, the largest in the world, are at Duluth.

GREAT NORTHERN RAILWAY LINE—Mesabi Division.

The Great Northern Railway line acquired what is now its Mesabi Division, over which line ore is transported from Mesabi range mines to docks at Allouez, Wisconsin, by purchase of the Duluth, Superior & Western railway (Duluth & Winnipeg) in 1898. At time of purchase this line extended from Duluth to Deer river, connecting with the Duluth, Mississippi River & Northern railway at Swan river, this latter road extending to the mines. In 1898 the purchase of the Duluth, Mississippi River & Northern road was effected, which gave the Great Northern a line through to Barclay Junction (now Chisholm), Minnesota. In 1900 and 1901 extension was built from Barclay Junction to Virginia, and in 1901 and 1902 line was built from Ellis (near Virginia) to a point on the old D. S. & W., known as Brookston now, then Stony Brook. In 1902 and 1903 what is now designated as the "South Range Line" was constructed from point near Hibbing (Kelly Lake) to connect with main line a few miles out of Virginia (Flanders).

There has also been built a "cut-off" known as the Kelly Lake-Fermoy line, running from point immediately south or east of Kelly Lake to west end of Fermoy, passing track on the Brookston line; length 23.4 miles; ruling grade, east bound 0.1, west bound 0.6. The actual distance from Kelly Lake to Fermoy is 24.074 miles. The object of this "cut-off" is to make a shorter haul between the mines and Allouez ore docks.

Allouez to Swan River, 87 miles; Swan River to Chisholm, 33 miles; Chisholm to Virginia, 18 miles; Ellis to Brookston, 46 miles; South Range line, 11 miles. There is a uniform grade of about .04 over entire Mesabi division.

Shops at Superior, Wisconsin. Ore docks and yards at Allouez, Wisconsin, for receiving ore lake end. Large assembling yard at Kelly Lake, for mine end.

DATA RELATING TO LOADING AND UNLOADING IRON ORE.

AVERAGE AND TOTAL ANNUAL TONNAGE, TIME LOADING BOATS, TIME PER 1,000 TONS. D. M. & N. RY. DOCKS.

Year.	Average Tonnage.	Total Tonnage.	Time Loading Hours.	Time Loading Per 1,000 Tons Hours.
1895	1809	1,598,783	4:00	2:13
1896	2214	1,988,932	5:16	2:24
1897	3541	2,371,000	7:40	2:10
1898	3350	2,635,264	8:10	2:07
1899	3803	3,509,965	7:24	1:57
1900	3873	3,888,986	6:31	1:43
1901	4459	3,437,955	5:57	1:20
1902	4814	5,598,408	7:09	1:29
1903	5668	5,356,473	8:47	1:33
1904	5679	4,649,611	10:55	1:56
1905	6037	8,807,559	11:11	1:51
1906	6973	11,220,218	12:47	1:50
1907	7516	13,445,977	10:07	1:21

MAXIMUM DAILY SHIPMENT.

Year.	Date.	Tons.
1904	Sept. 4	62,723
1905	June 30	86,340
1906	Sept. 16	112,589
1907	July 2	126,085

In 1906, Steamship E. J. Earling loaded 9,277 tons of iron ore in 70 minutes.

RECORD OF LOADING STEAMER AUGUSTUS B. WOLVIN, AUG. 5, 1904, GREAT NORTHERN DOCKS.

Boat arrived at dock	2:45 p. m.
Started to load	4:16 p. m.
Finished loading (about 9,000 tons)	4:50 p. m.
Shifted to complete cargo	45 minutes
Loading completed (10,245 tons)	5:45 p. m.
Total time at dock	3 hours
Total time loading	1:29

This cargo unloaded at Conneaut in 4 hours and 30 minutes.

DATA RELATING TO ORE CARRYING RAILROADS OF NORTHERN MINNESOTA.

NAME OF ROAD	Weight of Rails per Yard	Weight of Freight Locomotives in working order, with Tenders in Tons	Number of Freight Locomotives	Capacity of Standard Ore Cars in Tons	Number of Ore Cars
Duluth & Iron Range Railroad	80 and 100	Twelve Wheelers 132½ Ten Wheelers 118 Consolidations 98	43 Twelve Wheelers 6 Ten Wheelers 41 Consolidations	Steel Construction 50 Wood Construction 24	Steel Construction 2545 Wood Construction 4500
Duluth, Missabe & Northern Railroad	80	19 x 26 Cyl. 61½ 22 x 28 Cyl. 82	23 19 x 26 Cyl. 51 22 x 28 Cyl.	Steel Construction 50 Wood Construction 35 and 25	Steel Construction 4456 of 50 tons Wood Construction 1685 of 35 tons, 165 of 25 tons.
Great Northern Railroad Mesabi Div.	60 75 77½ and 85	4 Consolidation 106 10 Moguls 76 30 Prairie 103 2 Mastadon 112	46	Steel Construction 50 Large Wood Construction 50 Small Wood Construction 24	Steel 3300 Large Wood 400 Small Wood 600

During the shipping season of 1907 these three roads carried to lake ports 27,492,949 tons of ore. During one month (October) the Duluth, Missabe & Northern alone carired 2,502,255 tons.

YEARLY INDIVIDUAL MAXIMUM CARGO RECORDS.

Ships Passing Out of Lake Superior.

Steamers.

YEAR	Largest Single cargo Net Tons	Greatest Amount of Freight Carried Net Tons	Greatest Number of miles run	Greatest No. of Mile-Tons.
1900..	8,463	195,550	45,318	154,554,378
1901..	8,222	161,375	41,370	132,822,226
1902..	8,441	183,270	45,340	158,858,138
1903..	8,914	164,763	45,330	158,843,973
1904..	11,536	177,729	33,516	156,410,487
1905..	12,368	274,401	41,374	249,038,472
1906..	13,272	313,434	42,986	249,353,656
1907..	13,800	339,151	43,296	274,863,249

Sails.

YEAR	Largest Single cargo Net Tons	Greatest Amount of Freight Carried Net Tons	Greatest Number of miles run	Greatest No. of Mile-Tons.
1900..	8,206	149,091	30,947	124,399,966
1901..	8,288	125,301	26,424	99,429,012
1902..	8,485	250,258	32,032	119,437,488
1903..	8,671	128,201	26,569	114,536,002
1904..	8,736	117,365	24,158	106,643,498
1905..	9,184	155,772	31,481	127,243,648
1906..	8,960	141,770	31,575	126,745,992
1907..	9,408	152,144	27,039	121,205,504

Names of Vessels Making Above Maximum Records.

1900..	John W.Gates	Presque Isle	Troy	John W.Gates
1901..	W. Edenborn	Presque Isle	Buffalo	J. J. Albright
1902..	I. L. Elwood	W. Edenborn	Troy	W. Edenborn
1903..	W. Edenborn	John W.Gates	Buffalo	Bransford
1904..	A. B. Wolvin	A. B. Wolvin	Huronic	A. B. Wolvin
1905..	E. H. Gary	A. B. Wolvin	Duluth	A. B. Wolvin
1906..	J. P. Morgan	E. H. Gary	E. H. Gary	E. H. Gary
1907..	J. P. Morgan	J. P. Morgan	J. P. Morgan	A. B. Wolvin
1900..	Madeira	Madeira	Madeira	Madeira
1901..	Manila	Marsala	Sirl. L. Bell	Madeira
1902..	Jno. Smeaton	John Fritz	Alex. Holly	Marsala
1903..	Manila	A. Maitland	Barge No. 105	A. Maitland
1904..	Jno. Smeaton	A Maitland	Maida	A. Maitland
1905..	Jno. Smeaton	Manila	Marcia	Jno. Smeaton
1906..	Jno. Smeaton	A. Maitland	W.LeB.Jenny	Constitution
1907..	Jno. Smeaton	Jno. Smeaton	Jno. Smeaton	Jno. Smeaton

The maximum freight traffic through the canals for a single day was on August 26, 1907, when 487,649 tons were passed. The vessel passages on this day numbered 121, the aggregate registered tonnage being 287,385. Total traffic into and out of Lake Superior for the year was 58,217,214 tons, an increase over the year before of 7 per cent., and $38,458,345 were paid as freight charges. Of the total tonnage 68 per cent. was iron ore.

AVERAGE FREIGHT RATES ON IRON ORE PER GROSS TON FROM PORTS NAMED TO OHIO PORTS—TABLE COVERING WILD AND CONTRACT RATES FOR TWENTY YEARS PAST.

YEAR	ESCANABA		MARQUETTE		ASHLAND and other ports at the head of Lake Superior	
	Wild or Daily Rate	Contract Rate	Wild or Daily Rate	Contract Rate	Wild or Daily Rate	Contract Rate
1887	$1.50	$1.40	$1.87	$1.63	$2.23	$2.00
1888	1.05	.90	1.30	1.15	1.42	1.25
1889	1.01	1.00	1.19	1.10	1.34	1.25
1890	.89	1.10	1.07	1.25	1.17	1.35
1891	.84	.65	1.02	.90	1.11	1.00
1892	.74	1.00	.98	1.15	1.15	1.25
1893	.56	.85	.71	1.00	.77	1.00
1894	.46	.60	.60	.80	.78	.80
1895	.73	.55	92.	.75	1.13	.80
1896	.52	.70	.66	.95	.77	1.05
1897	.45	.45	.55	.65	.57	.70
1898	.51	.45	.60	.60	.62	.60
1899	.95	.50	1.08	.60	1.29½	.60
1900	.69½	1.00	.78½	1.00	.84½	1.25
1901	.64	.60	.79	.70	.89	.80
1902	.59	.60	.66	.70	.77	.75
1903	.61	.65	.72	.75	.81	.85
1904	.53½	.55	.62	.60	.70	.70
1905	.61	.60	.70	.70	.77	.75
1906	.60	.60	.70	.70	.75	.75
1907	.60	.60	.70	.70	.75	.75

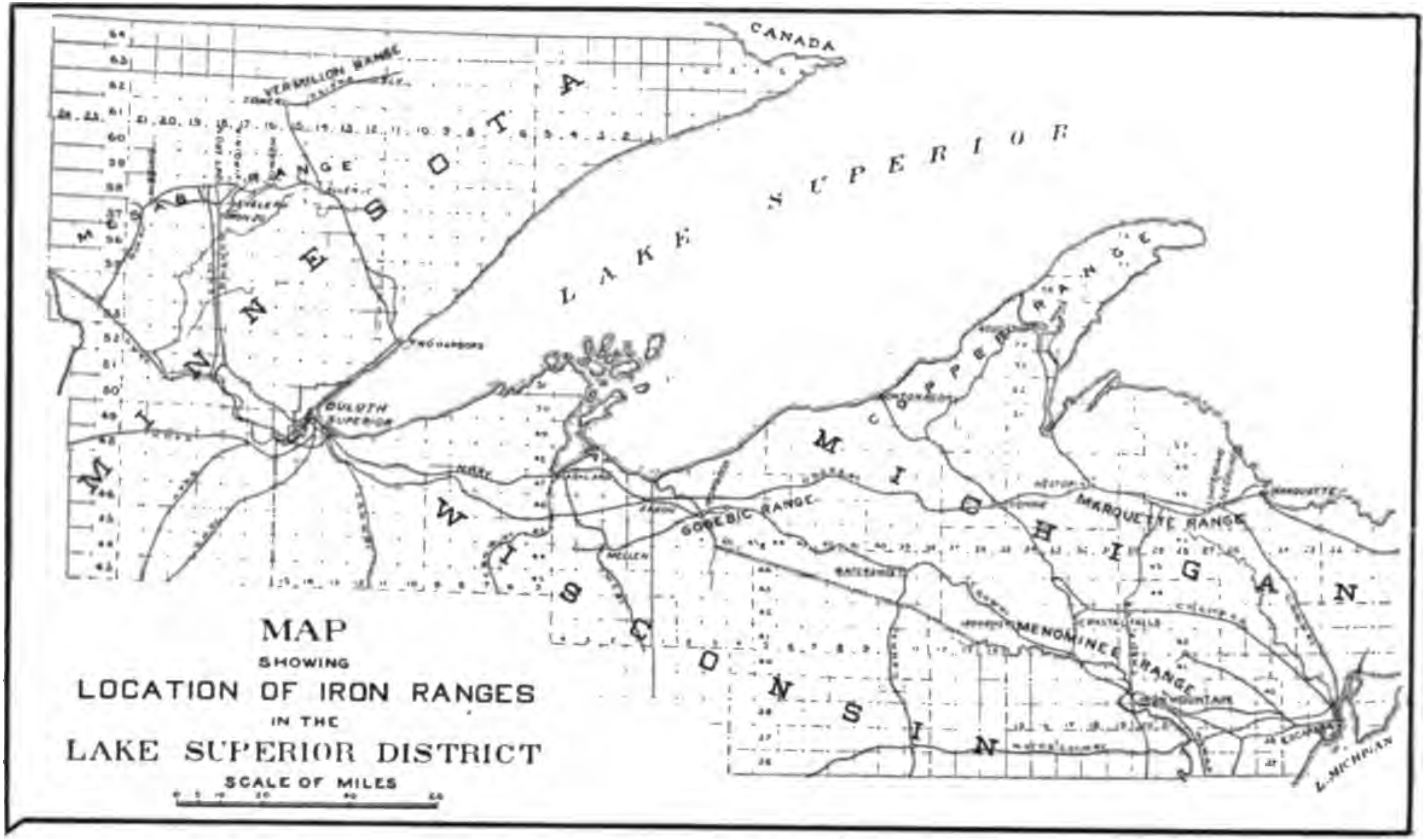
Charge to vessels in 1905 for unloading iron ore was 20 cents per ton. The wooden vessels that required trimming paid an additional charge of about 3 cents per ton for that service.

Average ore rates for the entire period of twenty years: Escanaba, wild 76 cents, contract 76 cents; Marquette, contract 91 cents, wild 91 cents; Ashland and other ports at the head of Lake Superior, contract 98 cents, wild $1.03.

Average for past ten years: Escanaba, contract 60 cents, wild 62 cents; Marquette, contract 71 cents, wild 72 cents; Ashland and other ports at the head of Lake Superior, contract 76 cents, wild 78 cents.

RAILWAY	LOCATION	Dock No.	Number of Pockets	Storage Capacity	Height, Water to Center of Hinge Hole	Height, Water to Deck of Dock	Width of Dock, Outside to Outside of Partition Posts	Length of Spouts	Length of Dock	Angle of Pockets
				Tons	ft. in.	ft. in.	ft. in.	ft. in.	ft.	DEG. MIN.
C. & N. W. Ry	Escanaba, Mich.	1	184	21243	28-10	48- 6	37- 0	21- 0	1104	39-30
" "	"	3	226	28792	31- 2	52- 8	37- 0	27- 0	1356	45- 0
" "	"	4	250	34925	36- 6	59- 2	37- 0	30- 0	1500	45- 0
" "	"	5	232	33663	28- 6	53- 3	37- 0	21- 8	1392	40- 0
" "	"	6	320	69760	40- 0	70- 0	50- 2	30- 0	1920	45- 0
" "	Ashland, Wis.	1	234	42120	40- 0	70- 0	50- 2	30- 0	1404	45- 0
" "	"	2	234	42120	40- 0	70- 0	50- 2	30- 0	1404	45- 0
	TOTAL		1680	272523						
D. & I. R. R. R.	Two Harbors, Minn.	1	202	40400	35- 5	59- 6	49- 0	27- 0	1388	38-42
" "	" "	2	208	41600	33- 5	57- 6	49- 0	27- 0	1280	38-42
" "	" "	3	170	34000	40- 0	66- 0	49- 0	27- 0	1054	43-32
" "	" "	4	168	36960	37- 0	62- 0	49- 0	29- 0	1042	38-42
" "	" "	5	168	35450	39- 0	66- 9	49- 0	30- 0	1050	43-32
		6	148	45880	40- 0	73- 0	53- 0	32- 4	1462	45- 0
	TOTAL		1064	234290						
D. M. & N. Ry	Duluth, Minn.	2	384	69120	32- 0	57- 6	49- 0	27- 9	2336	45- 0
" "	"	3	384	80640	40- 7	67-½	59- 0	27- 9	2304	45- 0
		4	384	119274	41- 9½	72- 6	57- 0	30- 1½	2304	45- 0
	TOTAL		1152	269034						
G. N. Ry	Superior, Wis.	1	374	100980	40- 0	73- 0	62- 8	32- 4	2244	45- 0
"	"	2	350	94500	40- 0	73- 0	62- 8	32- 4	2100	45- 0
		3	326	88020	40- 0	73- 0	62- 8	32- 4	1956	45- 0
	TOTAL		1050	283500						
D. S. S. & A. Ry	Marquette, Mich.	4	200	28000	27- 9	47- 3	36- 8	21- 1	1200	39-45
" "	"	5	200	50000	40- 0	70-10	51- 0	32- 4	1236	45- 0
	TOTAL		400	78000						
L. S. & I. Ry	Marquette, Mich.	1	200	36000	30- 9	54- 0	50- 0	27- 7	1232	38-40
W. C. Ry	Ashland, Wis.	1	314	48356	40- 0	66- 2	36- 0	27- 0	1908	50-45
C. M. & St. P. Ry	Escanaba, Mich.	1	240	50400	40- 2¾	66- 6	52- 0	[illegible]	1500	45- 0
" "	"	2	240	63500	40-11½	69- 2	54- 0	30- 4½	1500	45- 0
	TOTAL		480	113900						
Algoma Cen. & H. B. Ry	Michipicoten, Ont.	1	12		34- 0	43- 4	25- 0	22- 6	311-9	44- 0
Total Storage Capacity				1333603						

This table is compiled annually by the cheif engineer of the Duluth & Iron Range Railway, and includes the steel dock No. 6 of that road, not quite completed June 23rd, 1908.


CANADA
VERMILION RANGE
LAKE SUPERIOR
MINNESOTA
WISCONSIN
MICHIGAN
DULUTH
SUPERIOR
TWO HARBORS
GOGEBIC RANGE
MARQUETTE RANGE
MENOMINEE RANGE
MARQUETTE
MELLEN
L. MICHIGAN
MAP
SHOWING
LOCATION OF IRON RANGES
IN THE
LAKE SUPERIOR DISTRICT
SCALE OF MILES

MINUTES OF MEETING.

WEDNESDAY, JUNE 24TH, 1908.

Headquarters for the Institute were established at the Spalding Hotel, Duluth, where members and guests were provided with programs, badges and assigned accommodations for the trip to the ranges. There were about two hundred in the party. The afternoon was spent in a visit to the plant of the Great Northern Power Co., at Thompson and other points of interest in the city. The Duluth clubs and the Northland Country club entertained the members during the afternoon and evening until the departure of the trains at one o'clock Thursday morning. There were two special trains, one made up of C., M. & St. P. sleepers and diners and one of private cars. Some of the points of interest visited in Duluth are described in the program furnished for the occasion and printed in this volume. The brief stay in Duluth was much enjoyed by the members.

THURSDAY, JUNE 25TH, 1908.

At 5:30 a. m. the party arrived at Ely on the Vermilion range where the Chandler, Pioneer, Zenith, Savoy and Sibley mines were visited; leaving there at 11:00 a. m. and stopping for a brief visit at the Minnesota mine at Soudan near Tower. At this property work was first started as early as 1875, but no ore was shipped until 1884. This mine has to its credit a total shipment to the close of 1907 of 8,153,820 tons. During 1907 the shipments amounting to only 102,977 tons.

Leaving Soudan, the Biwabik, Fayal, Adams and Spruce mines on the Mesabi range were next visited, the train leaving

Eveleth at 6:30 p. m. for Virginia. The members found many improvements in the plants at the different mines since the last visit of the Institute, due mostly to the plan to standardize the buildings and equipment.

Upon arrival at Virginia at 7:15 p. m. the party was met by a committee of citizens who escorted them to the high school where the first business session was held. This is a beautiful three-story building of which the people of Virginia are justly proud, it indicates the thrift and enterprise of its citizens in thus providing for the education and welfare of its children.

EVENING SESSION.

The meeting was called to order by Mr. T. F. Cole, President. The attendance numbered two hundred and twenty-five members and guests. Mr. Cole introduced Mr. Louis M. Osborn, who had been delegated by the citizens of Virginia, to welcome the members. He spoke, as follows:

Mr. President and Members of the Lake Superior Mining Institute, our guests and fellow citizens: On behalf of our little city of 8,000 or 10,000 persons, we welcome you here this evening. We feel highly complimented that this most notable gathering of practical and scientific mining men should have chosen Virginia for one of its most important meetings. You are all busy men with limited time for this trip. We are glad you will be with us until ten o'clock tomorrow, and trust that you as a body, and also as individuals, will soon spend more time among us.

For those of you who have not been here before, it might not be amiss to say that you are now in the Roosevelt High school, almost directly in the center of the city. Four blocks to the north is the north limit, and the south boundary of the settled portion is seven blocks distant. Your trains are just four blocks to the east, with many active mines just beyond. From any portion of the city, this building will act as a guide post. Being the geographical center of St. Louis county and of the iron ranges, our four railroads make us the railroad center as well, and give us direct communication with Canada, and all points east, west and south. Our sister cities depend almost entirely upon their minerals. We have, in addition to many mines, three saw mills, the largest one having been built last summer at a cost of about a quarter of a million dollars. The oldest built, as you may have noticed, is now being remodeled for the purpose of cutting some 30,000,000 feet of timber for the Oliver Iron Mining Company. In spite of hard times, we are still growing. A new addition, platted about a year ago, has been entirely sold and half of the lots have already been built on. Uncle Sam has also been good to us. A few days ago free mail delivery was established here and congress has recently appropriated $60,000.00 for a federal building—the first city on these ranges to be so favored. We are now vigorously discussing where it should be built. We hope soon to have a city park—the first one in these mining towns—and pleasure boats on our two lakes, and when you next visit us, which we trust will be soon, you may hardly recognize Virginia.

Gentlemen, to Virginia now, and at all times, you are welcome, doubly welcome.

Mr. W. J. Olcott, of Duluth, Vice-President of the Oliver Iron Mining Co., responded to the address of welcome, as follows:

Mr. President, Mr. Osborn, Members of the Lake Superior Mining Institute and friends all: This world is one continual surprise; when I came here today I had no idea that I should be called from such a number more able to respond. Mining men, from the nature of their business, are operators. Many have been connected with large corporations, called closed corporations, told to say little or nothing and that the lawyer should do the talking; it is embarrassing, therefore, to be called upon with such short notice. We, however, feel such regard for the President of the Institute and our Company that when he asks us to do a thing we do it cheerfully and to the best of our ability.

We appreciate, as members of the Institute, the cordial welcome given by the people of Virginia. We appreciate also and congratulate you on the fact, that you have such a beautiful building to offer us in which to hold our meeting. I remember my first visit to Virginia in 1892, when there was only one small log building here and that was on the hill near the Missabe Mountain mine. Some people reported, before I made the trip, that the ore on the Missabe range was no good and would never be merchantable. However, I went on horseback from Mesaba station on the Duluth & Iron Range through to Hibbing, took my own samples from test-pits and found high-grade ore. Since then the territory around Virginia has been quite thoroughly explored and has developed deposits of ore that will last for many years. Unfortunately it is high in phosphorus, but it is a question of only a few years when the furnace people will have sufficient open-hearth plants to successfully handle this character of ore. When that time arrives Virginia will double in size and this building will be supplanted with other buildings to accommodate the children, which, I presume, you will have to fill them.

I just returned from a visit across the water and am glad to be able to say that during my twenty-five years in the mining business I have known and become associated with many classes of men and I think the Cornish people deserve the greatest credit for the progress made in mining in the Lake Superior region. They came from a country of sturdy manhood to our hard northern climate, encountered the dangers of pioneer mining and we owe more to them than any other race. I have heard these men tell Cornish tales, both amusing and interesting; heard them tell of the towns from which they came, their people and their friends, and no one can imagine the pleasure it gave me to go to the Levant mine, the big mine under the sea; to visit Penzance, Truro, Camborne and other towns. Camborne is the place from which many of our greatest mining men have come. I had the pleasure of going to the home where the Trezona brothers were brought up and it is a great credit to this country that these men have been so successful. It was a pleasure to go there and meet their family and receive such a cordial reception. I also had the pleasure of going to Liskeard, where Captain Goldsworthy was brought up, and going to the mine where he worked. These are only two of many examples that could be cited. There was no part of the trip through Italy, France, Switzerland, Germany and England that I appreciated more than traveling through the mining district of Cornwall. To be sure, I did not see many points to be gathered in the way of improvement in mining methods or equipment. Most of these mines are worked out or abandoned; those now working are operated under the most unfavorable conditions. They are hoisting at the Dolcoath mine from a depth of 3,000 feet, with one-ton skip. To dump these it is necessary to unlatch the door in the bottom and then latch it again by hand before lowering. It takes ten minutes to make a hoist and it takes two and a half to three hours to get the men out of the mine; they say four men get in the cage going down and six crowd in coming up. However, these are the mines where the start was made in mining, and the men who came over here, although they brought their homely ideas and primitive methods, have been the ones to take the lead and follow up improvements. Today we hoist in one shaft, in a month, as much as they hoist in a year. After traveling through the different countries and seeing the conditions under which the laboring classes work and live, the meager pay which they receive, the small opportunities for them to rise above their station, I come back to America loving my country better than ever before, appreciating the opportunities it affords a man, providing he has ability, courage and energy to get to the front, and I hope that each and every one of you will, whenever the opportunity presents, avail yourself of such a trip and, seeing conditions under which your fellow men work, I am sure you will come back feeling better satisfied with your own country, with a greater love for its institutions and laws and most important of all, you will look at conditions as they arise, from a much wider point of view.

Following the response of Mr. Olcott, President Cole addressed the members as follows:

PRESIDENT'S ADDRESS.

Members of the Lake Superior Mining Institute. I am sure that all the people, living on the iron ranges of Minnesota, join with me in extending to you a hearty welcome to this, the Thirteenth Annual Meeting of the Institute and it gives me much pleasure to greet you tonight. I assure you that your return will be looked forward to by the people of these ranges with a great deal of gratification.

I would like to call attention to a few facts regarding the work of the past two years in the Lake Superior mining districts. I will not attempt to go into details for papers on some of the subjects have either been prepared or will be written and presented at some future meeting.

Steel Construction—

The use of steel for mine buildings and head frames for shafts is increasing, in addition a considerable quantity of this metal is now used for frames to support the walls of shafts. Whenever it is possible to locate shafts in stable rocks affording a permanent and fairly secure outlet steel or concrete lining should be used. Danger from fire is lessened and the cubic feet of rock to be broken and hoisted is reduced by using steel frames instead of timber.

The Oliver Iron Mining Company is now planning to use steel frames to support the walls of the main openings such as drifts and crosscuts on each level instead of using large timber for such support. We expect to save money in protecting our drifts and crosscuts with this material for the large timber we will secure from our lands will then be cut into merchantable lumber, and good value can be secured for this product. The people of the country will be benefited for high grade lumber from that part of the tree free from knots and other defects is each year becoming more difficult to secure in requisite quantities. The first ore dock to be constructed of steel and concrete is now being erected at Two Harbors in this state.

Water Power Development—

Notable installation of structures, buildings and equipment to utilize the energy of water powers in the Lake Superior region have been made during the past two years; one at the Sturgeon Falls near Vulcan, Michigan, by the Penn Iron Mining Company,* the other at the falls on the St. Louis river near the City of Duluth. Conservation of natural resources should mean the development and utilization of energy that all our water powers will produce. The saving to the people of this nation is well illustrated by the fact that with ordinary waste in numerous steam power plants necessary to serve the growing industries located near the head of the lakes, the full utilization of this one water power near Duluth will equal the energy that can be secured from the output of a mine producing 1,300,000 tons of good steam coal per annum.

State governments should construct reservoirs of ample capacity to store flood waters and ensure an average flow of water in its rivers each day of the year, making a reasonable charge to individuals or power companies who may be benefited thereby.

Conservation of Forest Products—

United effort should be made by all members of this Institute to secure careful consideration by state officials and members of state legislatures of the important subject of conservation of our forests, and advocate the enactment of laws that will be just and equitable to all individuals or corporations who may desire to foster the growth of young thrifty timber and reforest areas of land that is not valuable for agricultural purposes, the soil of which is suitable for reforestation. Much

*This plant is fully described in the paper by Messrs. Orbison and Armstrong, entitled "The Hydro-Electric Plant of Penn Iron Mining Co." and published in this volume.—Secretary.

land of this character is now comparatively valueless and taxes are not being paid thereon.

Steel Manufacturing In the Northwest—

The decision of the United States Steel Corporation to erect blast furnaces and steel works to manufacture steel in Duluth is of tremendous importance to the people living in Minnesota, as well as in the entire Northwest. The raw materials to make iron can be assembled in Duluth at reasonable cost, and the volume of finished steel that should be distributed from Duluth is already a very important tonnage and is increasing in quantity very rapidly each year. From that city steel can be distributed to points comprising two-thirds of the area of the Dominion of Canada. The states comprising the Northwest are tributary to the head of the lakes and the mileage from Duluth to Omaha, Denver, Salt Lake City and San Francisco is the same as from Chicago. This means steel can be made in Minnesota and distributed in the middle Rocky Mountain states and the entire Pacific coast.

Western Missabe—

During 1906 and 1907 extensive development of the sandy ore deposits located in the Western Missabe district has been made. Openings in the ore disclosed the character of material to be concentrated. It was found the ore and sand would have to be subjected to a very effective abrading treatment before the mineral could be successfully concentrated. A committee was selected to visit the iron ore concentrating plants in the South, and Mr. John U. Sebenius of our engineering department with General Superintendent John C. Greenway, Mr. J. W. Leech, and Superintendent Dudley composed this committee. It was found the log washers used for concentrating the brown ores in Alabama would give the abrading effect required. It was decided to erect a temporary concentrating plant and install a log washer with other equipment, such as revolving screens and picking belt. The log washer not only is effective in giving the necessary treatment but it is a good concentrator and the improved type of log washer or Turbo invented by Mr. Greenway may be selected for the final treatment of material delivered by the log washer or caught from the overflow in settling tanks instead of revolving screens.

Valuable assistance was rendered by Doctor L. D. Ricketts of Cananea, Mexico, and William Nicholls, now in charge of the concentrating plants of the Nevada Consolidated Copper Company and Cumberland-Ely Copper Company operating in Nevada. Much credit is due the persons mentioned and their assistants for the successful outcome of the experimental work, and a concentrating mill with large capacity will be erected near Coleraine in the near future.

Mr. Cole then introduced Prof. N. H. Winchell, of Minneapolis, Minn. Mr. Winchell has long been identified with mining operations in the state and was among the first to report on the geology of the Vermilion and Mesabi ranges. His paper on the "Structures of Mesabi Ores," is published in this volume.

Mr. Spencer S. Rumsey, of the mechanical engineering department of the Oliver Iron Mining Co., Duluth, read a paper entitled, "Automatic Throttle Closing Device for Hoisting Machinery." This paper with complete drawings appears in this number.

Prof. L. S. Austin, of the Michigan College of Mines, Houghton, Mich., read a paper on "Sampling of Iron Ores," which was received with much interest. It is the object of the Institute to gather as much information as possible on this important subject and members are invited to prepare papers for the next annual meeting. Also to further discuss previous papers presented on this topic.

This concluded the reading of papers for the evening and the president on motion appointed the following committees to report at the session on Friday evening:

AUDITING COMMITTEE—John M. Bush, Ironwood, Mich.; Charles T. Kruse, Ishpeming, Mich.; Charles Grabowsky, Ely, Minn.

COMMITTEE ON NOMINATIONS—Frank E. Keese, Ishpeming, Mich.; Norman W. Haire, Houghton, Mich.; Charles H. Munger, Duluth, Minn.; Wm. J. Richards, Crystal Falls, Mich.; D. E. Sutherland, Ironwood, Mich.

On motion by Prof. F. W. McNair, of the Michigan College of Mines, a vote of thanks was extended by the Institute to the people of Virginia and the Commercial Club, for their kind reception and to Professor Bliss for the use of the school building for its meeting.

There being no further business the meeting adjourned to Friday evening, at Hibbing.

FRIDAY, JUNE 26TH.

The early morning was spent in visiting the mines at Virginia and at ten o'clock the party left to continue the trip over the range. The first stop was made at the Mountain Iron mine. This mine has the distinction of being the first discovered on the Mesabi range and was also the first in making shipments, and stands today at the head of the list in total tonnage. The guide prepared by Horace V. Winchell for the first meeting of the Institute, in March, 1895,* gives the date of the discovery of merchantable ore on the Mesabi range, as 1891 and 1892. It was in the latter year that the Mountain Iron mine made its first shipment of 4,245 tons, and for which year it was the only shipper from this range. The total tonnage up to end of 1907, is 16,992,173, which is the largest for any one mine in the entire Mesabi district.

At the Monroe-Tener mines the party was met by a reception committee from Hibbing. A train of seven flat cars equipped with comfortable seats had been prepared by the committee to take the visitors through the open pits where the regular coaches could not be handled. The party was conveyed by this observation train to Hibbing where the Morris, Hull-Rust and Mahoning mines were inspected. The train was taken to the bottom of the pits, affording a splendid opportun-

*Published in Vol. III, 1895, pages 11 to 32.

ity to see the workings. This feature added greatly to the interest of the trip.

The Institute was accorded a splendid reception by the citizens of Hibbing, a circular and map of the district had been prepared and was distributed to the visitors. A ball game between the Hibbing and Virginia teams being among the features of entertainment furnished. Following is copy of circular:

To the Members of the Lake Superior Mining Institute:

The citizens in general and the resident mining men in particular welcome you to the Hibbing district. Herewith will be handed you a map of the Hibbing district showing location of mines, roads, etc., also the shipments for 1907. Upon your arrival at the Monroe-Tener mine, a committee of one hundred of the representative citizens of Hibbing and vicinity, each bearing a badge with the inscription: "Reception, Ask Me" will meet and circulate among you; you will find them all good fellows and willing and anxious to do your bidding. After inspecting the mines in the east end of the district including the Hartley, Myers, Shenango, Monroe-Tener, Chisholm, Pearce, Clark, Leonard, Glen and Pillsbury, you will arrive at Hibbing between two and taree o'clock p. m.; and you will be given an opportunity of looking over the Morris, Albany, Buffalo, Burt, Sellers, Hull-Rust and Mahoning mines, among which you will see the largest exposed ore body in the world.

Not alone content with having the largest mines in the world, we believe we have the best base ball club in Northern Minnesota, and to those who enjoy this kind of amusement we will give an opportunity of witnessing a first-class article of ball between the home team and a team from Virginia. A separate section of the grand stand will be set aside for the members of the Institute and their friends; refreshments will be served and you are at liberty to root for the visiting team.

The parlors of the Algonquin Club will be open afternoon and evening to members of the Institute and also to any member of the local reception committee.

We will be glad to show you through our school buildings, our Carnegie library and would also be glad to show you our fair grounds.

In the evening at 8 p. m. you are earnestly requested to attend the business session of the Institute at the High school, and finally the mayor has kindly instructed the police force to see that you leave town on schedule time.

F. L. COVENTRY,
Chairman Reception Committee.

EVENING SESSION.

At 8:30 p. m. the members and guests together with many of the citizens of Hibbing, met at the auditorium of the High school where the business session was held. The program opened with several selections by the High School orchestra which were very well rendered. The meeting was called to order by President T. F. Cole who introduced the Rev. Frank Durant, delegated by the people of Hibbing to extend their welcome to the members. Mr. Durant spoke as follows:

Mr. President, members of the Lake Superior Mining Institute and friends: It is with great pleasure that we welcome you to our city. When the reception committees' badge was pinned upon my coat and the all-embracing words "Ask me" demanded some knowledge of your great industry I protested that iron mines and mining were a sealed mystery to me. I was then asked what I knew about copper, to which I could but reply, "I have some to sell"; the answer came, "There are more like you." We do welcome you most heartily to our city; we have endeavored to express that welcome since we met you this noon and it will be simply impossible for you, sleeping or waking, to get away from our care and oversight until you take your final departure from our midst. Indeed, we wish that your stay could be prolonged, that you might see something of the hospitality of our homes, the sweetness and beauty of our young womanhood, the graciousness of our wives and mothers; we have these in great abundance and gladly would we share them with you gentlemen of the Mining Institute.

In welcoming you I will not point with pride to our beautiful school buildings, symbolizing our interest in education. These things are our first thought and are characteristic of American interest everywhere; enough that Hibbing has them, that there are no better or finer anywhere and that this youngest and biggest and busiest range town—for it is that—has education as her first and chief concern. Neither will I point to you our Carnegie library—something to be had for the asking—but I do call attention to the splendid zeal that has mothered the enterprise and the greater zeal that will make our library one of the best institutions in our city.

Those of you who were here a few years ago cannot but see a vast improvement today, in the appearance of our store buildings, our substantial business blocks, and above all, the large and ever-increasing number of men and women pioneers of brain and brawn who are making for civilization in our northern country.

These iron ranges demand men and women of the highest type. There is no room for the mollycoddle. As a mother looks forward to the birth of her first born, longing for and awaiting the advent of a strong, manly character, so our range country longs and yearns and welcomes strong manhood and womanhood. There is no place for the weakling in her posts of position; the morally weak will be lost in the saloon and the low resort; the morally weak will find his place on the outskirts; the careless and indifferent will help fill the rank of the unemployed and dissatisfied. It is the strong and brave and true that are wanted and our town boasts of her fair share. As in the mines around here there is ore of many shades and grades, low and high, grading into finest bessemer, and the one strong quality in all is the iron, so with our men and women—many grades of workmen, many positions of trust and responsibility to fill, captains of industry, hardy workmen in the commercial and mining industries, and the one chief uniting characteristic of all is the iron in the blood.

To the town made by such men and women we bid you welcome—to Hibbing, the largest, busiest and biggest. We hope your visit here will be profitable and your hearts happy.

Responding to Rev. Durant, Mr. Cole spoke as follows:

On behalf of the members of the Institute I thank you for the hearty and cordial good will extended to us; the words you have spoken tonight were hearty. The greeting we received when we arrived at the Monroe-Tener mine was hearty; they had big and strong men there. It was good to our members to see the evidences of welcome on every hand.

All along, as we visited various mines on the Eastern Missabe, we saw lines of splendid locomotives and steam shovels awaiting the time when we could put them to work; they were prepared as for winter, being well greased and oiled to withstand any encroachment of the elements. I think last year there were none of these machines idle. There has come a financial depression. Many locomotives and steam shovels are idle because we cannot sell the ore. Copper suffered first. In the metal family it is looked upon as somewhat of a luxury, but it is a good metal; it is enduring and will withstand the ravages of the elements for all time; it is a beautiful metal and is today used for finishings of the high priced furniture that enters our homes; it enables mankind to take advantage of falling waters, but naturally it is a metal that is the first to suffer a decline when adverse conditions in the commercial world befall us. I want to say to you that we cannot sell iron ore freely this year and this is not an opportune time to sell copper at remunerative figures, but the day is coming when the metal will again be in demand and certificates will sell in the market at a figure that will more nearly evidence the real value of the mines on which they were issued. Say this to your good friends and the people of Hibbing. It may not be long before we will have to start the idle steam shovels and locomotives and it is not going to be long before the engineer will be ready with plans to utilize water powers and we shall again have prosperity in this land of ours. They cannot keep industry back for any long period.

The members of the Institute have evidenced their delight in Hibbing and its people and selected it as a place to hold a business meeting. The people of Hibbing not only extended us a hearty welcome today, but they even provided athletic exhibitions for us; I never saw a better ball game in my life than that played on the Hibbing field this afternoon, and with reference to the good wives, the mothers, the daughters; we know that they were pleased to have us with them; this was evidenced by their goodness in serving refreshments to the mining men. The residents of the city clearly evidenced their appreciation of our coming.

I believe it was six years ago since we met here and the development of the iron ore business in this district has been marvelous since that time. We hope by the time of our next meeting here your esteemed people will have enjoyed and be enjoying greater prosperity and the development has reached a point very much larger than it has today.

Mr. J. H. Hearding, of Eveleth, Minn., addressed the meeting on the subject of "Biographies of the Early Settlers of the Lake Superior District." This work was first suggested by Mr. Hearding at the Houghton meeting in August, 1906, since then he has devoted considerable time to the subject.

BIOGRAPHICAL ADDRESS BY J. H. HEARDING.

The Lake Superior region of the United States comprises the Upper Peninsula of Michigan, Iron, Ashland, Bayfield and Douglass counties of Wisconsin, and St. Louis, Lake and Cook counties of Minnesota, all of which territory lies adjacent to the lake and also practically includes Florence county, Wis., and adjacent territory on the Menominee iron range. The term itself, though not at all indicative, has grown to mean the mineral bearing districts and the mining regions which practically surround the lake itself, and the towns and cities that have grown up in consequence of the mining operations.

When the southern part of Michigan and Wisconsin were comparatively well settled regions, the Lake Superior country was practically a wilderness, populated by savages and game. Many rumors existed of untold mineral wealth, and in the latter part of the eighteenth century and the early part of the nineteenth century, one or two sporadic attempts were made to exploit this region by French and English explorers and capitalists, but these attempts proved fruitless, and the region again relapsed into its original quiet and obscurity.

It was not until 1840 or a little after, that the inhabitants of southern Michigan began to look towards the northern peninsula with any degree of interest, for it was at that time that Dr. Douglass Houghton was appointed State Mineralogist and commenced to investigate the possibilities of both peninsulas in the way of mineral wealth. His efforts were successful in many ways, but owing to his untimely end on the shores of the lake at Eagle river, at what was practically the beginning of his career, he accomplished much less than he would have, had he been spared. His investigations, however, attracted to the upper peninsula many men of many types who were associated intimately on account of their environment and unity of purpose, and these men eventually developed into what might be called a distinct type through the power of association.

That they impressed their personal character on their descendants and successors and that their characters were good and true, is attested by a statement made to me in 1904 by a Chicago machinery manufacturer, when he stated that he frequently would take a contract from a Lake Superior man and commence the manufacture of the material before a paper was signed, something which he never would do in other localities, a statement that certainly attributes a high standard of honesty and integrity to the men of this region. It is with the lives of these men that this paper has to deal, and any interest that it may excite is merely reflected from the memory of those that have gone before.

At the last meeting of the Institute at Houghton, I suggested to the meeting the preparation of biographical data relating to the lives of the prominent men in years past in the Lake Superior region. It was made as a suggestion, knowing that, if it were acted upon as a motion, the burden of the work would fall upon some one's shoulders, and I felt that, at that late hour, it could not be done without doing some injustice to the secretary of the Institute or some other person equally busy. Subsequently, Mr. Yungbluth asked me to prepare a paper bringing into it some of the biographies of the older men in the Lake Superior region; and for the last fifteen to eighteen months I have been trying to collect such biographies as I thought would be interesting. Before reading them I would like to present to the meeting a few ideas on the subject and would invite discussion of the same.

Biography as you all know is practically history, written in the form of the history of an individual and, therefore, should be as accurately stated as is possible, as in a few years it may become a matter of reference, and, if inaccurate, will cause a great deal of misstatement and confusion. The history of a given time is written in the lives of the men that lived at that time and were prominent in the affairs of the period. These affairs may not be of national importance, but they are of great local interest and very often are extremely valuable. The sources from which history is drawn are tradition, writings and personal memoranda of individuals, and public documents of record.

Tradition of necessity, must to some extent be inaccurate, as it depends largely on the memory of the person relating it and is therefore very likely to be colored to suit his ideas or prejudices, and should require corroborative evidence before being taken as a fact. An event related by one to another may seem entirely different to the person listening from what it actually is, and, if repeated by him, may give a very wrong impression of the original narrative. Personal memorandum has always the error of statement to contend with and the differences arising from the individual point of view. Public documents and records are the most accurate source of information, but even they at times are erroneous.

For these reasons I have felt that we should, in gathering this biographical data, have it presented to the meetings of the Institute, and as we still have in our midst many who were actually connected with the early days of the Lake Superior region, we can then have any errors in statement corrected as they are made in reading the biographies, and the records altered to agree with the facts. I find from my experience of the last few months in gathering the few biographies to follow, that in many instances letters will be written to people who are not conversant with the history of the individual desired, that some of the persons written to are absent from the address to which the letter is sent and that in some instances the letters are not answered on account of apparent indifference or neglect. Of course one cannot blame a correspondent who often is too busy to answer or who cannot find the data desired, for it certainly necessitates a good deal of investigation.

In regard to the data to be used; that which especially applies to the history and development of the Lake Superior region should be of primary importance; other side lights in the history of the individual are interesting and instructive but what would seem to me to be the essential part would be the individual's connection with the work in the Lake Superior region. Of course outside influences that lead up to the persons coming to the Lake Superior region are also important. Another way of furthering the work would be to have the members of the Institute send in names of those whom they know of but whose histories they do not know, and these can be referred to others who are familiar with or have access to the facts and the results can be obtained in that way. An effort was made in this direction by the secretary in a circular letter, sent to members in April, 1907, but was productive of but one biography, hence I am making a personal appeal to you all to send them in.

We also have as members of the Institute most all of the newspaper men in the mining region and, if they would send in any obituary notices that they may print, they would confer a great favor on the person preparing the data and greatly facilitate the work. Another point is that it would seem most fitting that the biographies of all of our deceased members of the Institute should be published in our records. At present we have 35 names in our list and I think they should all appear, with biogaphical notices in the proceedings.

There is, of course, a great temptation to ask some of the older members to write the story of their lives and work, but it involves a great deal of work on their part and without wishing to appear flippant would be a good deal like asking a man to write his own obituary notice. If, however, they could be persuaded to present papers dealing with their connection with the Lake Superior region, they certainly would confer a great favor on the members and add greatly to the pleasure of all of us. I think though that such requests should come from the President of the Institute rather than from a private individual believing it to be much more courteous and effective, and I think that an evening with the pioneers would be as enjoyably a feature for all as could be introduced.

From my short experience I feel that whoever takes up the work in the future should have provided for him, a suitable letter head by the Institute. If it devolves on the Secretary, of course, the official letter head of the Institute will be all that is necessary, but to have a private individual write to you for personal and intimate data regarding the life of one who was near and dear to you is even a little worse than to be questioned by a total stranger as to the size of your pocketbook. For that reason I have introduced myself very frequently to strangers, to whom I have written by using my official letter head, hoping thereby to add at least the respectability of the company to my request. Then in conclusion comes the question, who is to do the work, if it is to be done, and further, if the Institute wishes to extend it from this insignificant beginning, and assume the extra expense of printing its proceedings.

It would appear that a committee of interested and patriotic members would be the easiest and most efficient way to carry on the work, but that point is certainly up to the meeting. Personally I believe the work should go on and should be made a feature of our transactions. We all are more or less interested, and we all may well be for the Northern Peninsula from

1843 to 1870 was by no means an Elysian field. The climate during the summer was certainly delightful, excepting such things as sandflies, mosquitoes, gnats and the like, but as late as '69 there was no connection by rail with the Copper Country and when winter came with unusual force as it most always did, the hardy band of pioneers located at the different settlements were absolutely cut off from civilization, excepting for a monthly mail by dog sledge delivered by one of our own sturdy members, the Hon. Peter White. Since this article was written he has passed beyond to be numbered with the illustrious dead of this Institute. I had hoped that he might be present to correct and amplify the data submitted.

I have a keen recollection of many of the incidents told me by my mother of the early sixties in Houghton and they can be duplicated from all of the old settlements such as Ontonagon, Hancock, Marquette, L'Anse and others. Cut off from all intercourse with civilization, the inhabitants of the U. P. had to live by themselves and for each other, and such a condition must produce either very bad or very good results. The character of the men and women who went to the Upper Peninsula at that time was such that they developed within this environment, as broad a charity, as high principles of honor and integrity and as wide and hearty a hospitality as has ever been known in the history of our country.

Mr. Yungbluth: I think that the manner in which Mr. Hearding has started this feature of the work in connection with the Lake Superior Mining Institute, and the progress he has made the first year of the effort, suggests the advisability of continuing the research for information along the lines mentioned in his paper. In securing the biographies of the pioneers of the mining regions of the Lake Superior district, we will also secure more or less data which is of great importance, historically, and I would like to see this made a permanent feature. Instead of throwing the whole burden of the work upon Mr. Hearding it might relieve him somewhat if a committee would be appointed to assist him, of such men as have some personal knowledge and information in regard to the early days, and selected possibly with a view to covering the different ranges. The copper country would perhaps offer the earliest information and much has already been gathered up by Mr. Hearding with a view of accomplishing something in this direction. I would suggest further consideration and discussion as to future work relative to biographical and historical research for the benefit of the Institute and for the informaton of people who read the proceedings. I might state that the proceedings are now placed in many of the libraries of the United States; also in Canada, England, Australia, Germany and South Africa. Our work seems to be appreciated; only recently we received request for a complete set of volumes for the Calumet & Hecla library and you will find extracts quoted in various books in connection with work along mining and metallurgical lines.

The first paper for the evening was read by Mr. William Kelly, of Vulcan, Mich., on "The Hydro-Electric Plant of Penn Iron Mining Co., at Vulcan, Mich.," which was prepared by Mr. Thomas W. Orbison, of Appleton, Wis., and Mr. Frank H. Armstrong, of Vulcan, Mich. The paper was illustrated by stereopticon views, showing many very interesting pictures during construction as well as after completion of the plant. The work on this plant was begun in the fall of 1905 and completed in the spring of 1907.

Mr. Alexander M. Gow, of the mechanical department of the Oliver Iron Mining Co., presented a paper entitled, "The Standard Boiler House of the Oliver Iron Mining Co." At some of the mines visited during the trip the members had the opportunity to carefully inspect the type of building described in this paper.

Dr. Alfred C. Lane, State Geologist of Michigan, prepared an exhaustive paper on the subject of mine waters and presented a brief abstract of the same. The paper is published in full in this volume.

Mr. W. F. Slaughter, of Republic, Mich., read a paper entitled, "Acetylene Gas As An Underground Light." The writer gives the results of some tests made as to the efficiency and economy of this method of lighting.

Following the reading and discussion of papers, the Secretary presented the report of the Council since the last meeting.

REPORT OF THE COUNCIL.

The Secretary's report of Receipts and Disbursements from August 8th, 1906, to June 16th, 1908, is as follows:

RECEIPTS.

Cash balance on hand August 8th, 1906		$4,396.12
Dues for 1906	$1,895.00	
Entrance fees, 1906	285.00	
Back dues	250.00	
Advance dues, 1908	100.00	
Sales of proceedings	71.65	
Sale of Institute pins	248.00	
Total	$2,849.65	
Interest on deposits	254.78	
Total receipts		3,104.43
Grand total		$7,500.55

DISBURSEMENTS.

Stationery and printing	$ 69.85		
Postage	151.20		
Freight and express	23.89		
Telephone and telegrams	14.61		
Secretary's salary	750.00		
Clerical and stenographic work	62.50		
Total		$1,072.05	
Publishing proceedings, Vol. XII—			
Printing and binding	$576.50		
Advance papers, 1906, 1908	153.25		
Photographs, maps and cuts	317.99		
Total		$1,047.74	
Institute pins		379.00	
Badges for 1907, meeting postponed		135.00	
For badges and expenses, meeting 1906		196.12	
Total disbursements			$2,829.91
Cash on hand June 16th, 1908			4,670.64
Grand total			$7,500.55

Membership—	1908.	1906.
Members in good standing	444	410
Honorary members	4	4

Life members	1	1
Members in arrears	26	50
Total	475	465
New members admitted	60	64
Members not qualified	3	7
New members added	57	57

TREASURER'S REPORT.

The Treasurer's report from August 8th, 1906, to June 16th, 1908, is as follows:

Cash on hand August 8th, 1906	$4,396.12	
Received from Secretary	2,849.65	
Interest on deposits	254.78	
Paid drafts issued by the Secretary		$2,829.91
Cash on hand June 16th, 1908		4,670.64
	$7,500.55	$7,500.55

The undersigned committee appointed to audit the books of the Secretary and Treasurer, beg leave to report that they have carefully examined the same and find them to be in accordance with the above statements.

We have also examined the bank statements and find that the deposits agree with the cash statement.

CHAS. T. KRUSE,
JOHN M. BUSH,
Committee.

The following applications for membership have been received since the last annual meeting and are approved by the Council:

Adgate, F. W., Civil Engineer, Kansas City, Mo.

Amberg, William A., President Loretto Iron Co., 438 Fulton St., Chicago, Ills.

Angst, Robert A., Mine Superintendent, Hibbing, Minn.

Benson, A. F., Chief Engineer Republic Iron & Steel Co., Virginia, Minn.

Biscombe, Joseph R., Mining Captain, Kearsarge, Mich.

Binney, Joseph, Mining Captain, McKinley, Minn.

Bowen, Reuben, General Sales Manager, Fred M. Prescott Steam Pump Co., Milwaukee, Wis.

Brewer, L. C., Superintendent Newport Mine, Ironwood, Mich.

Brown, John Jacob, Mechanical Engineer, 1539 First National Bank Bldg., Chicago, Ills.

Chamberlain, Paul F., Assistant Superintendent, Soudan, Minn.

Chambers, H. P., M. D., Florence, Wis.

Cheyney, H. C., Assistant General Freight Agent, C. & N. W. Ry. Co., 215 Jackson Blvd., Chicago, Ills.

Connors, Thomas, Timber Contractor, Negaunee, Mich.

Cotter, W. H., Carbon Salesman, 108 Fulton St., New York City.

Coyne, William, Traffic Manager, E. I. DuPont de Nemours Powder Co., Wilmington, Del.

Croxton, David T., Iron Manufacturer, Cleveland, Ohio.

Damkroger, H. C., Mining Engineer Oliver Iron Mining Co., Coleraine, Minn.

Dawe, Peter, Mine Inspector, Houghton Co., Calumet, Mich.

Donovan, Percy W., Superintendent of Explorations E. J. Longyear, Hibbing, Minn.

Dormer, George H., Superintendent Fayal Mine, Eveleth, Minn.

Drake, Rollin E., Secretary Vermillion Pine & Iron Land Co., Ishpeming, Mich.

Duff, Harry E., Mining Captain, Riverton Mine, Iron River, Mich.

Edwards, J. P., Mining Captain, Mansfield, Mich.

Fairchild, David L., Diamond Drill Contractor, 616 Lonsdale Bldg., Duluth, Minn.

Ferguson, J. A., Northern Sales Agent, Pittsburg Coal Co., Duluth, Minn.

Glass, Frank A., Mining Engineer, Randall, Minn.

Harden, James H., Broderick & Bascum Rope Co., Stratford Hotel, Chicago, Ills.

Hart, William C., Mining Engineer, Hibbing, Minn.

Henderson, Enoch, Manager Copper Crown Mining Co., Matchwood, Mich.

Hine, S. K., Iron Manufacturer, Girard, Ohio.

Hodgson, J. A., Broker, Houghton, Mich.

Hunner, Earl E., Civil and Mining Engineer, Hibbing, Minn.

Kerr, George H., Manager Sales Records E. I. DuPont de Nemours Powder Co., Wilmington, Del.

Koch, Arthur A., Instructor of Analytical Chemistry, Michigan College of Mines, Houghton, Mich.

Kruse, Charles T., Assistant Superintendent Pittsburgh & Lake Angeline Iron Co., Ishpeming, Mich.

Lamont, John D., Mining Engineer, Virginia, Minn.

LaRue, William G., Mining, 208 Exchange Bldg., Duluth, Minn.

Latham, Arthur M., Chief Clerk Meriden Iron Co., Hibbing, Minn.

Lewis, Charles H., Manager of Mines, Hibbing, Minn.

Lindberg, John F., Superintendent Diamond Drills, Hibbing, Minn.

Linn, A. E., Mining Engineer, Norway, Mich.

Martin, Alfred, Superintendent of Mines, Virginia, Minn.

Matthews, William C., Assistant Director of Sales, E. I. DuPont de Nemours Powder Co., Wilmington, Del.

Meyers, William R., Mining Engineer, Princeton, Mich.

Moore, Clarence E., Mining Superintendent, Virginia, Minn.

Morris, Charles S., Mining Engineer, 2232 E. First St., Duluth, Minn.

Murray, Robert, Superintendent, Hibbing, Minn.

McCammon, George H., General Sales Agent Beall Bros., 753 Railway Exchange Bldg., Chicago, Ills.

Orton, Hugh J., Mining Engineer, Hibbing, Minn.

Pentecost, John, Mining Captain, Calumet, Mich.

Quinn, Clement K., Mining Engineer, Virginia, Minn.

Richards, Morris E., Mining Engineer and Mining Superintendent, Buhl, Minn.

Roskilly, Joseph, Superintendent of Mines, Virginia, Minn.

Russell, C. W., Assistant Manager, Russell Wheel & Foundry Co., Detroit, Mich.

Savage, J. A., Mine Superintendent, Hibbing, Minn.

Schulze, W. J., Mining Engineer, Virginia, Minn.

Simmons, Charles, Machinist Foreman, Champion Mine, Beacon, Mich.

Smith, Willard J., Mining Superintendent, Mohawk, Mich.

Skinner, Mortimer B., Vice President and Secretary, James McCrea & Co., 63-65 W. Washington St., Chicago, Ills.

Smith, George M., General Agent, C. & N. W. Ry. Co., Duluth, Minn.

Tappan, William U., Mine Superintendent, Hibbing, Minn.

Thieman, Edward, Cashier, Florence, Wis.

Thompson, Greer H., Contractor, Hibbing, Minn.

Thompson, Henry S., Assistant Superintendent Oliver Iron Mining Co., Beacon, Mich.

Tillinghast, Edmund S., Mining Engineer, Lutonia Mine, Hibbing, Minn.

Tobin, James, Retired Mining Captain, Florence, Wis.

Van Evera, Wilbur, Mining Engineer, McKinley, Minn.

Webb, Francis J., Mining Inspector, St. Louis County, Eveleth, Minn.

Wearne, William, Superintendent, Laura Mine, Hibbing, Minn.

Welker, W. F., Assistant Superintendent, C. & N. W. Ry. Co., Ashland, Wis.

Wessinger, Henry J., Chief Engineer, Oliver Iron Mining Co., 610 Wolvin Bldg., Duluth, Minn.

Williams, Percival S., Assistant Superintendent, Montreal Mine, Montreal, Wis.

The Council recommends that the Secretary be paid the salary of seven hundred and fifty dollars for the past year.

On motion the report of the Council was adopted and the

Secretary instructed to cast the vote of the Institute for the election of the applicants presented.

The report of the Auditing Committee was read and adopted.

Mr. Walter Fitch, of Calumet, Mich., presented the following resolution which was on motion adopted:

Resolved, That Messrs. J. H. Hearding, W. J. Olcott, Geo. A. Newett and J. B. Cooper be requested to act as a committee to consider the character and scope of the records, to be prepared for publication in the Proceedings, covering the Lake Superior mining industry and a biography of the individuals concerned in its early history and submit to the Council such plan, and the Council be authorized to pass and approve such plans as it may see fit, and authorize the committee's expenditures.

On motion by Mr. Dwight E. Woodbridge, of Duluth, a vote of thanks was tendered to the committee and the citizens of Hibbing for the splendid reception given to the members and the entertainment provided during their stay. Also to the authorities for the use of the school building and the members of the High school orchestra for the music furnished.

The committee on nominations presented the following report:

Your committee on nominations beg leave to submit the following names as officers of the Institute for the term specified:

For President: (one year)

M. M. Duncan, Ishpeming, Mich.

For Vice-President: (two years)

1, W. J. Richards, Crystal Falls, Mich.
2, Charles Trezona, Ely, Minn.

For Managers: (two years)

1, F. E. Keese, Ishpeming, Mich.
2, W. J. Uren, Calumet, Mich.
3, L. M. Hardenburgh, Hurley, Wis.

For Treasurer: (one year)

1, E. W. Hopkins, Commonwealth, Wis.

For Secretary: (one year)

1, A. J. Yungbluth, Ishpeming, Mich.

F. E. KEESE,
C. H. MUNGER,
W. J. RICHARDS,
D. E. SUTHERLAND,
NORMAN W. HAIRE.

The report of the committee was on motion adopted and the Secretary instructed to cast the vote of the meeting for the election of the officers as presented by the committee.

Mr. Walter Fitch presented the following resolution which was on motion unanimously adopted:

Resolved, That the thanks of this Institute be tendered to the Mining Companies of Minnesota and their officials and to the Clubs and Citizens of Duluth for the very handsome entertainment extended to the Institute and its members on the occasion of their visit to the cities and iron ranges of the state.

After announcement being made of the program for Saturday, the meeting was on motion adjourned.

SATURDAY, JUNE 27TH, 1908.

At seven o'clock Saturday morning, the members arrived at Coleraine and were met by the band and members of the Commercial club. The local members took the party in charge and after boarding the observation train a trip was made through the Canisteo and Walker pits. The concentrating mill was next visited, and considerable time was spent here. This mill was erected to carry on experimental work before construction on the large plant was begun. The committee conducted the party through the new town to the John C. Greenway High school. As we are promised a paper on Coleraine for this issue no extended mention is here necessary. The trains left for Duluth at 12 o'clock noon, arriving there at four where the party disbanded.

The thirteenth meeting will be long remembered by those present. The arrangements were admirably carried out which made it possible to cover so large an area in so short a time. Mr. Cole and his associates are to be complimented on the great success of the meeting.

The following is a partial list of members and guests in attendance at the meeting:

ABEEL, GEORGE H....................................Hurley, Wis.
ABELL, S. J..Chicago, Ills.
AMBERG, J. WARD....................................Chicago, Ills.
AMBERG, W. A. ....Chicago, Ills.
ANGST, R. A..Hibbing, Minn.
ARMSTRONG, F. H...................................Vulcan, Mich.
AUSTIN, L. S..Houghton, Mich.

BACON, L. H. ....Ishpeming, Mich.
BARTLETT, E. P.....................................Chicago, Ills.
BAXTER, CHARLES H. ....Loretto, Mich.
BEYENKA, THOMAS ....Houghton, Mich.
BIRCKHEAD, LENNOX.......... ....South Milwaukee, Wis.
BLACKWELL, FRANK ....Ironwood, Mich.
BLACKWELL, FRANCIS ....Ironwood, Mich.
BOWDEN, F. J.......................................Houghton, Mich.
BOWEN, REUBEN ....Milwaukee, Wis.
BREMER, D. F...Chicago, Ills.
BREWER, K. W.......................................Chicago, Ills.
BREWER, LUTHER C.............................Ironwood, Mich.
BRIGHAM, E. D.......................215 Jackson Blvd., Chicago, Ill.
BROUGHTON, H. P..................................Duluth, Minn.
BURR, FLOYD L.......................................Vulcan, Mich.
BUSH, JOHN M.....................................Ironwood, Mich.

CAMPBELL, S. G...................................Bessemer, Mich.
CARMICHAEL, WILLIAM ....Biwabik, Minn.
CARPENTER, C. S...................................Duluth, Minn.
CARSON, JOHN A..................................Appleton, Wis.
CARTER, R. B...Chicago, Ills.
CASTLE, WILLIAM B.............................Marquette, Mich.
CHAMPION, CHARLES ....Champion, Mich.
CHEYNEY, H. C......................................Chicago, Ills.
CHINN, W. P. ....Hibbing, Minn.
CLARK, KIMBELL ....Ironwood, Mich.
CLIFFORD, J. M....................................Escanaba, Mich.
COAD, RICHARD ....Ely, Minn.
COLE. CHAS. D....................................Ishpeming, Mich.
COLE, T. F..Duluth, Minn.
COLE, WM. H...Duluth, Minn.

COLE, WM. T....................................Ishpeming, Mich.
COOPER, JAMES B.................................Hubbell, Mich.
COTTER, W. H. ....New York City, N. Y.
COVENTRY, F. L..................................Hibbing, Minn.
CRANE, E. E......................................Duluth, Minn.

DAVIDSON, O. C.............................Iron Mountain, Mich.
DICKENSON, E. S............................Iron Mountain, Mich.
DORMER, GEORE H.................................Eveleth, Minn.
DUDLEY, HARRY C...............................Coleraine, Minn.
DUFF, HARRY E................................Iron River, Minn.

EATON, LUCIEN ....Iron Belt, Wis.
EISELE, GEORGE J...........................Iron Mountain, Mich.
ELLARD, H. F.................................Silver City, N. M.
ELLIOTT, MARK...................................Virginia, Minn.
FAIRBAIRN, C. T..................................Duluth, Minn.
FAIRCHILD, D. L..................................Duluth, Minn.
FAVOR, GEO. W....................................Chicago, Ills.
FAY, JOSEPH ....Marquette, Mich.
FISHER, JAMES, JR..............................Houghton, Mich.
FITCH, WALTER ....Calumet, Mich.
FLODIN, NELS P................................Marquette, Mich.
FOLEY, DAVID F...................................Duluth, Minn.
FRASER, WILLIAM H..........................Crystal Falls, Mich.

GRABOWSKY, CHARLES ....Ely, Minn.
GILBERT, C. B. ....Duluth, Minn.
GLASS, FRANK A. ....Deerwood, Minn.
GODFREY, M. H. ....Hibbing Minn.
GOLDSWORTHY, JOSEPH ....Iron Mountain, Mich.
GORDON, ALEXANDER T.......................Mountain Iron, Minn.
GOW, A. M..Duluth, Minn.
GREENE, W. E. ....Cleveland, Ohio.
GREENWAY, JOHN C..............................Coleraine, Minn.
GRIERSON, EDWARD S..............................Calumet, Mich.
GUNSOLUS, F. H..............................Wilmington, Del.

HAIRE, NORMAN W................................Houghton, Mich.
HULL, E. M. ....Chicago, Ills.
HAMMOND, T. A. ....Duluth, Minn.
HARRIS, S. T...................................Houghton, Mich.
HARRISON, G. E..................................Hibbing, Minn.
HARTLEY, G. G....................................Duluth, Minn.
HART, WILLIAM C.................................Hibbing, Minn.
HAWKINS, M. S..............................Mountain Iron, Minn.
HEARDING, JOHN H................................Eveleth, Minn.
HEARLEY, MICHAEL T.............................Cleveland, Ohio.
HELPS, S. E. ....Eveleth, Minn,

HEYN, HOWARD J....Ishpeming, Mich.
HOLLY, V. C. ....Marquette, Mich.
HOLMAN, J. W....Chicago, Ills.

JACKSON, H. L....Princeton, Mich.
JONES, JOHN T. ....Eveleth, Minn.
JOHNSTONE, O. W. ....Abbotsford, Wis.
JONES, CHARLES C....Ramsey, Mich.

KARKEET, J. H....Iron Mountain, Mich.
KEESE, FRANK E....Ishpeming, Mich.
KELLY, WILLIAM ....Vulcan, Mich.
KIESWETTER, CHARLES W....Duluth, Minn.
KING, C. B....Ishpeming, Mich.
KIRKPATRICK, J. CLARK....Escanaba, Mich.
KNIGHT, R. C....Eveleth, Minn.
KOEPEL, ED....Beacon Hill, Mich.
KOCH, ARTHUR A....Houghton, Mich.
KRIEGER, A. H....Duluth, Minn.
KRUSE, CHARLES T....Ishpeming, Mich.

LAMBRIX, GEORGE ....Hurley, Wis.
LAMBRIX, MICHAEL ....Hurley, Wis.
LANE, ALFRED C....Lansing, Mich.
LANG, T. H. ....Duluth, Minn.
LARSON, EDWARD....Florence, Wis.
LA RUE, W. G....Duluth, Minn.
LAWTON, CHARLES L. ....Hancock, Mich.
LEONARD, C. M. ....Princeton, Mich.
LESLIE, S. I. ....New York City, N. Y.
LETZ, JOHN F. ....Milwaukee, Wis.
LEWIS, CHARLES H....Hibbing, Minn.
LEIN, NELS....Eveleth, Minn.
LINDBERG, F. C. ....Hibbing, Minn.

MACKIE, E. M....Chicago, Ills.
MANEY, E. J....Duluth, Minn.
MARS, WILLIAM P....Duluth, Minn.
MATTHEWS, WM. C....Wilmington, Del.
MYERS, W. R. ....Ishpeming, Mich.
MINER, ANSON B....Ishpeming, Mich.
MITCHELL, WM. A. ....Chicago, Ills.
MONROE, W. G....Iron Mountain, Mich.
MOORE, CLARENCE ....Virginia, Minn.
MORGAN, DAVID T....Ishpeming, Mich.
MOWATT, NEVILLE P....Houghton, Mich.
MUNGER, CHARLES H....Duluth, Minn.
McCORKINDALE, W. J....Ishpeming, Mich.
McDONALD D. B....Virginia, Minn.

McDOWELL, JOHN ....Hibbing, Minn.
M'GEE, M. B. ....Crystal Falls, Mich.
M'GREGOR, SILAS J..........................Iron Mountain, Mich.
McLAUGHLIN, H. ....Iron Mountain, Mich.
McLEAN, JOHN H.................................Duluth, Minn.
McNAIR, F. W...................................Houghton, Mich.

NEWETT, GEORGE A............................Ishpeming, Mich.
NINNESS, EDMUND ....Ironwood, Mich.
NORMAN, J. L. ....Duluth, Minn.

OLCOTT, WILLIAM J...............................Duluth, Minn.
ORR, FRANK D. ....Duluth, Minn.

PASCOE, PETER W...............................Republic, Mich.
PASCOE, WILLIAM ....Republic, Mich.
PENTECOST, JOHN...............................Calumet, Mich.
PHILLIPS, W. G..................................Calumet, Mich.
PRESCOTT, FRED M............................Milwaukee, Wis.
PRESHO, E. W. ....Hughton, Mich.
POWELL, D. W. ....Marquette, Mich.

QUINE, JOHN T.................................Ishpeming, Mich.
QUINLAN, J. H. ....Houghton, Mich.
QUINN, JOHN H.................................Ishpeming, Mich.

RAISHLEIGH, WM. ....Aurora, Minn.
RAISKY, F. H...................................Ishpeming, Mich.
READY, CHAS. W..................................Chicago, Ills.
RICHARDS, WILLIAM J.......................Crystal Falls, Mich.
ROBERTS, HARRY ....Duluth, Minn.
ROBERTS, RICHARD ....Negaunee, Mich.
ROBINSON, JAMES A...............................Hibbing, Minn.
ROSS, D. E. ....Eveleth, Minn.
ROUGH, JAMES H.................................Negaunee, Mich.
RUMSEY, SPENCER S. ....Duluth, Minn.
RUNDLE, A. J..............................Iron Mountain, Mich.
RUSSELL, C. W...................................Detroit, Mich.

SAMPSON J. D....................................Ashland, Wis.
SAVAGE, J. A. ....Hibbing, Minn.
SCHULZE, W. J..................................Virginia, Minn.
SHEA, JOHN ....Negaunee, Mich.
SHERRERD, JOHN M.........................High Bridge, N. J.
SHIELDS, IRVIN J................................Duluth, Minn.
SHIPMAN, CHARLES G................................Ely, Minn.
SHUBERT, GEO. P. ....Houghton, Mich.
SIEBENTHAL, W. A. ....Republic, Mich.
SILLIMAN, A. P. ....Hibbing, Minn.
SISLEY, GEO. E. ....Chicago, Ills,

SKINNER, M. B. ....Chicago, Ills.
SLAUGHTER, W. F. ....Republic, Mich.
SMITH, W. J. ....Mohawk, Minn.
SMITH, GEORGE M. ....Duluth, Minn.
SOADY, HARRY ....Iron Mountain, Mich.
SPITZER, J. D. ....Ishpeming, Mich.
SPORLEY, CHARLES L. ....Negaunee, Mich.
STEPHENS, JAMES ....Ishpeming, Mich.
STOEK, H. H. ....Scranton, Pa.
SULLIVAN, F. J. ....Ironwood, Mich.
SUTHERLAND, D. E. ....Ironwood, Mich.
SUTHERLAND, W. G. ....Eveleth, Minn.
SWAIN, R. A. ....Duluth, Minn.
SWIFT, GEORGE D. ....Duluth, Minn.

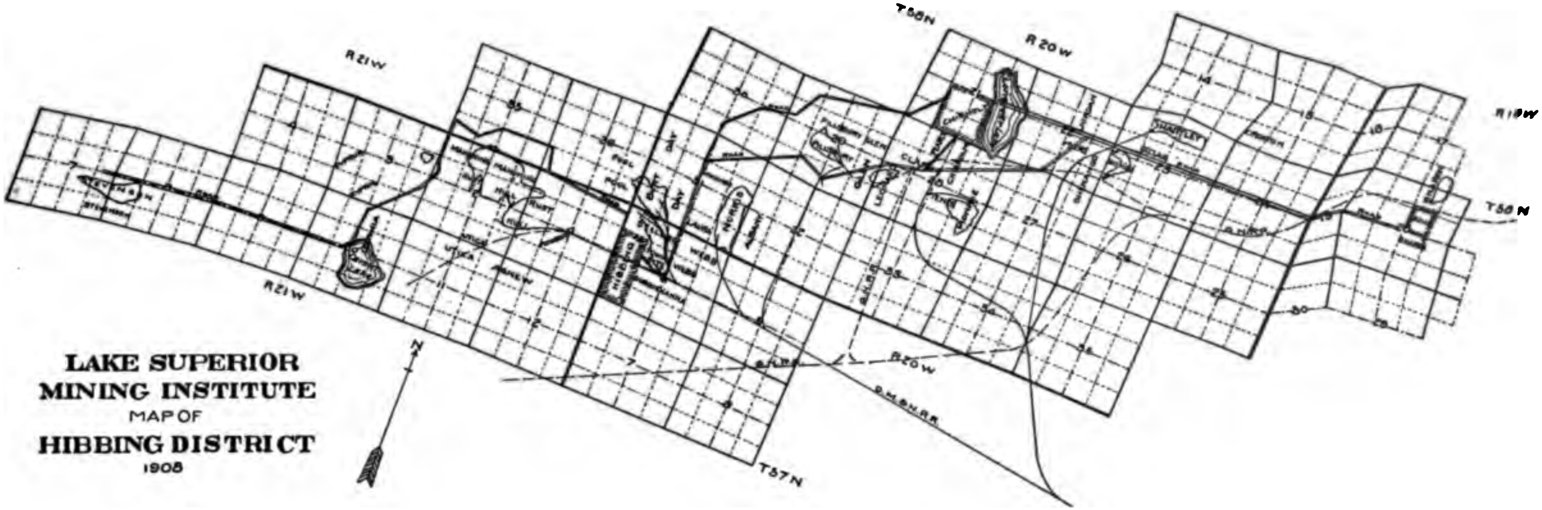
TARR, S. W. ....Duluth, Minn.
TAPPAN, WILLIAM M. ....Hibbing, Minn.
THOMPSON, G. H. ....Hibbing, Minn.
THOMPSON, HENRY S. ....Beacon, Mich.
TILLSON, F. P. ....Ishpeming, Mich.
TREBILCOCK, JOHN ....Ishpeming, Mich
TREZONA, CHARLES ....Ely, Minn.
TRIPP, CHARLES D. ....Chicago, Ills.
TRUETTNER, IRVING W. ....Bessemer, Mich.

UREN, WILLIAM J. ....Calumet, Mich.

VANDEVENTER, JOSEPH ....Ishpeming, Mich.
VAN HAGEN, G. E. ....Chicago, Ills.
VAN VALKENBURG, ALLEN J. ....Chicago, Ills.
VOGEL, FELIX A. ....New York City, N. Y.

WARE, J. F. ....Dayton, Ohio.
WARREN, O. B. ....Hibbing, Minn.
WEBB, CHARLES E. ....Houghton, Mich.
WELKER, W. F. ....Ashland, Wis.
WENSHEIMER, E. C. ....Ishpeming, Mich.
WESSINGER, H. J. ....Duluth, Minn.
WEST, WM. J. ....Hibbing, Minn.
WHITEHEAD, L. G. ....Duluth, Minn.
WILLIAMS, J. P. ....Schullsburg, Wis.
WINCHELL, N. H. ....Minneapolis, Minn.
WIVELL, WILLIAM ....Nashwauk, Minn.
WOLVIN, A. B. ....Duluth, Minn.
WOODBRIDGE, D. E. ....Duluth, Minn.

YUNGBLUTH, A. J. ....Ishpeming, Mich.



PRODUCTION FROM MINES IN THE HIBBING DISTRICT FOR 1907.

Name of Mine.	Tons-1907.						
Agnew	149,084	Glen	205,426	Mahoning	1,564,332	Sellers	155,060
Albany	437,521	Hartley	334,646	Monroe	156,809	Shenango	387,093
Burt	1,501,272	Hull	157,366	Morris	2,076,388	Stevenson	1,142,977
Chisholm	258,793	Hull-Rust	2,900,493	Myers	153,770	Susquehanna	137,207
Clark	319,983	Jordan	61,996	Nassau	19,172	Tener	190,903
Croxton	349,853	Laura	149,410	Pearce	68,886	Utica	304,864
Cyprus	260,948	Leetonia	301,368	Pillsbury	489,718	Webb	113,334
		Leonard	137,316	Rust	213,355	Winnifred	94,867

MINE WATERS.

By Alfred C. Lane.

(With Chemical Assistance Especially of Dr. G. Fernekes.)

INTRODUCTION.

Some two years ago* I brought the question of the chemical character of the deeper mine waters to the attention of the members of the Lake Superior Mining Institute. As a result quite a body of facts was with their help obtained which lead to some conclusions which are practical and "important if true". I will summarize some of these beginning with those which are most firmly established.

GENERAL INFERENCES.

1. *Both in the iron country and in the copper country* the surface waters are soft as compared with those of the Mississippi valley.

2. *Both in the iron country and copper country*, with increasing depth the amount of chlorine increases, and in time becomes more than enough to combine with the sodium. The calcium (lime) rises, too, so that we may say that calcium chloride is present. Such waters are extremely corrosive on boilers and pumps, and of course hard.

3. In this presence of calcium chloride they resemble waters which are found in the older rocks all over the Mississippi valley, in fact more or less all over the world. They seem to have been in part at least buried with the strata. Such waters laid down with the strata when they were laid down may be called connate waters, for short.

*Volume XII, L. S. M. I. pp. 154-163.

4. Flows of the deeper or connate water decrease and generally soon drain off.

5. The strength of these connate waters varies greatly, but below 1500 feet it is not uncommon to find them stronger than sea water.

6. Both iron and copper deposits are found in chutes of waters working downward.

7. In both cases there is a tendency to accumulate iron oxide in place of sodium silicate which goes into solution, the silica being later precipitated and the sodium remaining as sodium chloride in solution taking the place of calcium chloride.

8. In both cases, but more especially in the copper country the downward wandering of the surface water may be ***not wholly a mere up and down circulation, but an absorption of water by the strata, like a sponge.*** To such an extent as this is true the formation of ore chutes is not limited by any chance for circulating waters to escape, but may extend to an indefinite depth, after passing a zone of greatest richness.

9. In both cases the downward course of the water and the formation above is likely to be more active where the surface topography favors it, under high ground for instance. But such a feature is by no means the only or most important factor. A porous or fractured condition of the beds aiding circulation. and impervious dikes or clay seams to concentrate and guide the flow are also important, and there is no reason why ore chutes may not occur under low ground.

Of course in details of reaction, deposition, and structure the copper and iron countries differ very widely, and I do not know anything about the mine waters of Minnesota, which may introduce entirely new factors. It seems therefore better at present to separate our handling and treat the waters of the iron country and the copper country separately.

Before final publication some tests of mine waters have been added.

To properly treat and present various tests and analyses variously incomplete, by various men and at various times is not very easy. It has seemed on the whole best to give all the references that I know to Lake Superior mine waters in a nearly historical order, with the original figures, conditions of sampling and occurrence, authorities, etc., distinguishing as carefully as possible the results of computations, and then to follow this with a discussion of what seem to me the siginficant facts.

It will be noticed that most, if not all, the organic matter and ammonia will be eliminated from the total solids heated to incipient fusion, and that any remainder might be more than balanced by loss of chlorine and CO_2. Thus extremely small differences between total solids and the sum of the constituents determined do not *of necessity* imply that such constituents were not present.

Since in these studies we have to guard against being misled by the effects of human contaminations, nitroglycerine fumes and urine, it may be well to include an analysis of a urine* made by Parkes as follows:

Water	1500 grains contains
total solids	72 made up as follows:
Hydrocarbons.	
Urea C O H_4N_2	33.18
Uric acid $C_5H_4\ N_4O_3$	.555
Hippuric acid $C_9H_9NO_3$	.400
Kreatinin $C_4H_7N_3O$	.910
Pigment	10.
Sulphuric acid	2.012
Phosphoric acid	3.164
Chlorine	7.000
Ammonia	.770
Potassium	2.500
Sodium	11.090
Calcium	.260
Magnesium	.207
SiO_2, Fe	trace
Nitrates, sugar, gases, etc	small

Normal urine varies in concentration from Sp. Gr. 1.015

*From the New International Cyclopedia.

to 1.025. It is quite clear that no serious adulteration with urine or nitroglycerine could be introduced without introducing quantities of nitrogen in some shape—it might be oxidized to nitrates that should be recognizable. It is also clear that the tendency of such adulteration will be to increase the relative proportions of sodium.

No such adulteration can change our general results.

I. IRON COUNTRY MINE WATERS.

The first definite indication of calcium chloride waters in the iron mines came to my attention in testing to see whence a flood of water in the lower levels of the Vulcan mine might have come. From the analysis of this water, page 155 of the annual report for 1903, taken in connection with the surface water analyses (p. 156) I inferred an admixture of a small quantity of calcium chloride water, and that there was no *direct* connection with the surface, or the alkalis would be higher. I suspected this flood to be connected with caverns in the Randville dolomite, and it is said (priv. com. W. Kelly) to come from the talcose underlying schists.

The temperature of the water at the 12th level, 1,000 feet from the surface, was: at the shaft, 57.°2 F.; at the first winze, about 100 feet west of the shaft, 60.°6; and the west end, almost 300 feet west of the shafts, 58.2°. (See annual for 1901, p. 246). According to the observations there, the mine water at 1,210 feet was 56°, and at 270 feet, 45.°8. This water is then, abnormally warm—either from working up(?) or the heat from casing, friction and decayed timber.

The question arose whether it had any immediate surface source, and accordingly, analyses were made of the surface waters, which will be found in the Annual for 1903, p. 156. In them the chlorine is from 3.8 per million down, the alkalis high.

In this flood water* the output increased from 600 gallons per minute to 2,000, the increase being from a flow of water in the pump station on the 15th level. About Dec. 10, a sam-

*Priv. Com. Agent W. Kelly, Mar 10, 1907, and earlier.

ple was taken and analyzed, column (1). On March 19, 1904, it reached a maximum of 2,807 gallons and has since fallen off fairly steadily, being not much affected by the seasons. By March 26, 1907, the flow had fallen to about 1,000 gallons per minute when it was analyzed again by Dr. G. Fernekes with the results given in column 2. The decrease was principally in the flow in the 15th level pump station which "comes from the talcose slates underlying the north ore formation".[1] In the mean time at the west end of the 15th level a flow was struck "coming from the slates overlying the north ore formation", 1,300 feet west, about Sept. 1, 1906, amounting to about 250 gallons a minute, and this was tested, analysis 3.[2] Comparing these Vulcan analyses 1, 2 and 3, it is clear that the hardness remains fairly constant, and there is always practically all the bicarbonate it can hold if there is no excess of CO_2,[3] but with time and the addition of the new sources at the west end the chloride is dropped, the alkalies rose and approached the amount in the surface waters. Judging from the analyses of the talcose schists given by Bayley (loc. cit.) the alkalies are not leached from them or the Randville dolomite, and the first water struck which had no alkali *seemed* to come from that direction. The abundance of potassium relative to sodium column 2, may be connected with the fact (loc. cit. p. 379-389) that potash was found in 11 of 15 samples of ore analyzed, soda in but five and generally seems less abundant in the ore. The later analyses and the exhaustion of the flood which has come to pass show quite clearly that no mistake was made in inferring from the analysis that it was not directly from the surface and would run down.

Analysis (1) has the characteristic of the early connate waters, chlorine high relative to sodium.

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1 U. S. G. S. Mono. 46 by Bayley, p. 221-2, p. 452.

2 Analysed by G. Fernekes, May 10, 1907.

3 Volume VIII, Part 3, saturation is 95 parts per million Ca, 105 fixed, 210 total CO2,

VULCAN MINE WATERS.

	1	2	3
Insoluble matter, clay & SiO_2	4.4		
Solid solubles	340.00	344.00	303.63
Organic matter	52.3		
Carbon dioxide	37.3	163.00	171.00
Non volatile solids	250.4		
In solution.			
SiO_2	5.8	9.8	11.2
Al_2O_3	4.4	18.2	1.7
Fe_2O_3	trace		
Ca	60.3	62.29	62.3
Mg.	37.7	28.20	30.5
SO_4	43.0	13.14	11.2
Cl	61.	18.68	
K.	trace?	13.	3.7
Na K	p. n. d tr.	6.	11.03
Sr. Li.	0		
Total by addition	209.2	332.31	
Diff., organic, and undetermined Li, Ba, Cr, etc		11.96	

Analyses in parts per million. Analyst, for 1 and 2, G. Fernekes. Location given above.

In the same way the Ishpeming mine water (loc. cit. p. 157), given below, shows a greater amount of chlorides than is at all normal to the superficial waters of the Upper Peninsula, though not so much that it might not be attributed to organic contamination, which however, the geological conditions render unlikely.

An Ishpeming mine water, collected by A. Formis, coming out of a diamond drill hole at a depth of 825 feet, gave the following results:

1	2
Lime as carbonate	15.8
Oxide determined	31.3
Magnesium as carbonate	17.0
Oxide determined	8.1
Oxide determined	.7
Iron and alumina carbonate	.5

Oxide determined		34.3
Requiring CO_2	33.2	
Total encrusting solids		73.3
Chlorides as sodium chloride		56.2
Chlorine determined		34
Sulphates as sodium sulphate		67.0
SO_3 determined		33.4
Total corrosive solids		123.2
Silica		10.5
Water of crystallization[1]		3.2
Excess of CO_2		1.1
Combined CO_2		33.2
Sodium chloride		56.2
Organic matter by difference from ignition loss		19.9
19.9. Ignition loss		113.6
Total by computation		229.1
Total by evaporation at 105° C.		232.2
Difference (minor errors, extra weight of potash over soda and undetermined)		3.1

Analysis by Kirschbraum, computation by A. C. L.

I took, myself, with Mr. E. A. Separk, the chemist, a sample of water from the Aurora mine, Gogebic range, 200 feet west from A shaft about 900 feet down, on the fifth level at a point which had been opened five months. The temperature of the water as taken was 67° F.; of the drift at a dryer place 57° F. The water was coming down on top of the 60-foot kaolinized dike which crosses the formation there.

The analysis is as follows:

December 8, 1904.

Sample marked—Oliver Mining Co., Aurora mine water, Ironwood, Michigan.

	Grams per Ton.
Total solids	1420
Loss on ignition	544

1 The sulphates are probably in large part calcium sulphate, etc., and the soda correspondingly carbonate, reducing the amount of crystallization water.

Silica	122
Iron and aluminum oxides	012
Lime	354
Magnesia	150
Sulphuric anhydride	044
Chlorine	160
Sodium oxide	037
Carbon dioxide	510
Organic matter	034

F. K. Ovitz, Analyst.

Upon evaporating fifty cc. of the water to which a few drops of hydrochloric acid had been added to three or four cc. the spectroscope showed no test for potassium. No phosphorous was found. The organic matter is taken as difference between loss on ignition and carbon dioxide.

We may suppose this combined as:

$CaSO_4$	.8	grams per ton
NaCl	7.0	
$CaCl_2$	18.3	
$CaCO_3$	46.6	
$MgCO_3$	48.3	
$FeCO_3$	1.7	
SiO_2	12.2	
Organic	3.4	
CO_2	4.7	
	143.0	

Here again while the total solids are not greater than might be found in any surface water, and the chlorine not greater than might have been artifically introduced, the amount of chlorine is more than twice what can be combined with the alkalies (Na : Cl :: 23 ; 35.5 :: .0037 : .0057) and the presence of calcium chloride and the admixture of a small quantity of water containing this in solution must be inferred. The bulk of the water is percolating downward no doubt.

Sometimes the amount of residual chlorine is so great as to affect the use of the mine waters in boilers. This instigated the following tests of the Hurley (Superior and Ottawa) mine waters given me by Mr. Geo. H. Abeel.

The chlorine is sometimes said to be "free" but I think this really means in the boiler. Of course a weak solution of calcium or magnesium chloride may also be considered as a solution of calcium or magnesium hydrate and H Cl.

These tests were made for the Wickes Brothers, boiler manufacturers. No. 1 is of a sample taken from boiler at the end of the usual running period; No. 2 from the heater during operation; No. 3 of the raw (mine) water delivered to heater. It may be added that the water from the fifth level shows no free acid, and only .34 grains of chlorine per U. S. gallon. The chlorine is said to have become noticeable at 400 feet depth. The boiler water has also no free acid according to another report but 15.04 grains per U. S. gallon or 258 per million of chlorine.

	1	2	3
Mineral matter	43.79*	18.88*	14.79*
Organic matter	17.98	4.35	3.19
Mg	.78	.58	.49
Iron and alumina	.116	.058	.174
(A trace of iron)			
Ca	11.09	2.59	2.31
SO_3	6.04	1.87	2.4
Cl	13.92	3.94	3.48
Oil	present	present	present
Reaction	acid	acid	
Solids suspended			5.5

Iron in combination with oxygen or sulphur.

Additional tests at the Yale mine obtained through Mr. Abeel give the following results:

New or West Colby at 9th level 40 parts per million chlorine
Yale down to 15th level....... 225 parts per million
Yale down to 20th level....... 709
Yale 10th down to 20th level. 1070 parts per million Cl; Ca 429

The upper two tests by E. B. Smith, the lower two by Koch.

I have been on the watch for something stronger. This I was enabled to obtain through the kindness of Peter W.

*The figures are in grains per U. S. gallon.

Pascoe of the Republic mine, who reported such a water at a vertical depth of 1153 feet from the surface in the 16th level, 600 feet northwest of the No. 9 shaft. With Messrs. Siebenthal, Slaughter and Pascoe I visited several places in the deeper part of the mine where saline waters came in, testing with total reflectometer and urinometer, and taking a sample of the strongest.

At 1153 feet down, 600 feet northwest of the No. 9 shaft a drip from a drill hole and fissure which has a temperature of 55° F, precipitated iron freely on the floor of the drift, seemed fresh and showed an index of refraction, near that of fresh water corresponding to a Sp. Gr. of 1.009 or so. On the 1435-foot level, say 100 feet from No. 9 shaft, was another flow, temperature 59° and there was a still more appreciable amount of salt. On the 1710 level near the Pascoe or south end of the mine the strongest water was almost drained off* from a fissure making an angle of 32° with the drift, dipping 24° or so north of west. The temperature was 57° to 57½°, the Sp. Gr. by urinometer 1.025 to 1.027. The analysis by Dr. G. Fernekes is as follows:

	Parts per million grams per ton.
Ca	7,902
Na	7,290
Mg	566
Cl	25,360
SO_4	1,045
CO_2	not determined
Al_2O_3	700
Mn	tr
Fe	tr
Sum	42,863
Total solids	45,590

We may for comparison suppose this combined as:

Na Cl	18,510
Ca Cl_2	21,800

*It is characteristic of the strong calcium chloride waters that they appear in limited quantity. More than once I have been told of one by a mining captain, and upon going to the place not found enough to test. Somewhere lower we might find it.

$CaSO_4$	822
$MgSO_4$	381
$MgCO_3$	1,560
Al_2O_3	700
Fe, Mn, SiO_2, etc	1,617
	45,590

From the Champion Iron mine a sample was sent in by the agent, W. H. Johnston, which came from the 28th level, 800 feet east of No. 5 shaft. It gave the following results:

Sp. Gr. 1.0037. This would correspond to about .5% $CaCl_2$ and .51 NaCl.

	Per Grams per Ton
Total solids by evaporation, including combined and crystal water	7,100
Chlorine Cl	3,050
Calcium Ca	810
Sulphate iron SO_4	370
Alumina Al O_3	present
Carbonates CO_2	very low
Iron	0

M. A. Cobb, Analyst.

This may be assumed to be:

Sodium and magnesium chloride	3,120
Calcium chloride	1,780
Calcium sulphate	520
Calcium carbonates	00
Balance of solids on evaporation mainly crystal water united with calcium sulphates and chloride	1,680
	7,100

The ratio of Ca ; Cl = .27 is not very far from that of the Republic sample just cited (.313).

Salt water is also said to have come out of a drill hole south from the 17th level No. 4 shaft and no doubt traces of calcium chloride water could have been found higher up if tested for. It must not be forgotten that we get news of it only when it gets so strong as to appreciably affect boiler waters.

II. COPPER COUNTRY WATERS.

1. The first published analysis of Lake Superior mine waters of which I know is that of Silver Islet, within sight of Isle Royale but on the Canadian side of the boundary.[1]

2. I am told*, however, that notably salt water was about the same time struck in the Cliff mine at about sea level and that Mr. L. G. Emerson, one of the more prominent of the early engineers who assisted R. Pumpelly in the preparation of Volume I of these reports, took samples of the same and made some tests, but I have found no printed reference to the same. It was probably struck therefore about 1879.

The water in the Silver Islet mine** was noted also for the presence of combustible gas, which came in vugs penetrated by drills with salt water below 500 feet. Two gallons gave a pint of acid and deliquescent calcium chloride.

The salt water I am informed by W. M. Courtis, who was employed as chemist there, came in a bore hole on the north side of the shaft at the 9th level (560 feet from the surface) in 1878. At the request of Dr. Selwyn a sample was collected by Mr. Tretheway and analyzed by G. C. Hoffman in 1882.

The results were as follows:

1. Total dissolved solids by drying at 180°C. 39.9566 per thousand.

Potassium chloride	.4582
Sodium chloride	16.8098
Calcium chloride	17.0867
Magnesium chloride	1.2937

1 This should perhaps be geologically included with the iron country waters as it occurs in Huronian rocks, but it is very strong and may be associated with a Keweenawan intrusive.

*W. W. Stockley says at about sea level. Johnson Vivian, says 1800 feet down. The plan of the mine in the Min. Stat. report for 1880 shows the bottom of the mine at the 2200 bottom level, 1680 below the top of the greenstone, and it was soon after abandoned, the vein being a "cold green quartzite", the rocks much slicken sided and muddy.

**See Canada Geological Reports H. 1887, p. 28, 58.
W. McDermott, Eng. & M. J., Feb. 3, '77, p. 53.
T. Macfarlane, Trans. A. I. M. E., VIII, 1880, p. 226; XVII, p. 296, and earlier volumes, i. e., IV, V, IX, XV, p. 671.

Calcium sulphate	.0672
Calcium carbonate	.2936
Silica	.0540
Sum	36.0632

Comment and Calculated Figures.

The difference between the solids and the sum is quite probably in large part crystal water.

We calculate.

Cl	22.53
Na	6.45
Ca	6.23
SO_4	.047
CO_3	.177

Na : Cl .287

Combustible gas is often found in old mine workings and some of the best informed men, who have had painful experience with it do not think it comes from decaying mine timber and the like.

Dr. R. T. Chamberlin has found gases absorbed in the rock of fresh drill cores, taken far from the present surface.

3 and 4. Franklin mine. The next analysis published and the first I personally heard of was the one made by Prof. R. L. Packard, of water reported by an error as from the *Huron* mine, in Wadsworth's annual report for 1892, p. 174.

The full figures, both of the analysis of the mine water and of the boiler water are given below.

Attention was first called to it and the analysis made because of the trouble it made in the boilers. This was when the mine was down to the 25th or 26th level (1610′ on the lode) about 1300′ below the surface. I am assured* by Capt. Vivian that the sample was really from the Franklin.

---

* Houghton, Dec. 12, 1905.

The water from the Franklin mine that was analyzed by Prof. Packard was taken, I think, from a depth of about 2,800 feet on the line of the lode which dips 54 degrees. It was about the average of the mine from a depth of about 2,500 feet to where it was taken. From the surface to a depth of 1,500 or 1,600 feet the water was as it seems good enough to drink. I remember hearing Mr. L. G. Emerson say that the first water of the kind that we had in the Franklin was found in the Cliff mine at a depth of 1,800 feet perpendicular.

Yours respectfully,

(Signed) J. VIVIAN.

The water from the boiler contained a large quantity of salts in solution besides a large sediment.

"Its specific gravity was 1.04951, and on evaporation it left a residue, deposited from solution, of 69.09 grammes per 1,000 grammes of water, or 4027 grains per gallon. Disregarding the sediment, the residue left insoluble on evaporating to dryness and the organic matter the water contained in 1,000 parts.

Chlorine	39.171
Lime	14.727
Magnesia	.144
Sulphuric acid (SO_3)	.417
Carbonic acid (combined)	.110
Potassa	.850
Soda	17.651

These figures may be combined as follows:

Sodium chloride (common salt)	33.265
Calcium chloride	30.467
Potassium chloride	1.345
Calcium sulphate	.622
Magnesium suphate	.078
Magnesium carbonate	.248

"The mine water had a specific gravity of 1.00647 and contained 8.515 grammes of soluble salts in 1,000 grammes of water, or 496 grains to the gallon. Neglecting the organic matter and insoluble residue the water contained in 1.000 parts.

Chlorine	4.739		Sodium chloride	4.021
Lime	1.9293		Calcium chloride	3.553
Magnesia	.0493		Potassium chloride	.163
Sulphuric acid	.145	or	Calcium carbonate	.056
Combined carbonic acid	.079		Calcium sulphate	.247
Soda	2.132		Magnesium carbonate	.104
Potassa	.103			

Very truly yours,

(Signed) R. L. PACKARD."

COMMENTS AND COMPUTATIONS.

The ratio of K : Na : Cl in the boiler water and mine water is practically the same. Some sulphate and carbonate of lime and magnesia have been deposited as scale from the boiler water, but on the whole they check each other up very well, and we have:

4.	Cl	4.739 per thousand
	Na	1.583
	Ca	1.378
	K	.086
	Mg	.030
Fe, Al, Si p.n.d. compare following analysis.		
	Organic	
	CO_3	.088
	SO_4	.174
		8.078
Undetermined		0.437
Total solids		8.515
	Na:Cl	.33
	Ca:Cl	.29

5. Franklin mine. Some time in the 80's another analysis was made of the Franklin mine[1] water, as follows:

Franklin Copper Mine Company—

	U. S. Gallon. grains.
Silica	7.813
Iron sesquioxide	1.022
Alumina	.932
Lime	63.911
Magnesia	5.463
Potassa	5.433
Soda	59.952
Carbonic acid	1.945
Sulphuric acid (SO_3)	10.596
Chlorine	156.828
Organic matter	1.566
Total	315.461

COMMENT AND COMPUTATION.

This is very much like 4, contains a little less sodium in

1 Messrs. Clow & Son got this made in Chicago but never gave the name of the man that made it.—J. Vivian.

proportion, but otherwise, and even in minor ingredients potash, magnesia, carbonate and sulphate checks with No. 4 quite well . This, like 3 and 4, is in analysis of the mine water as pumped and contains the deeper water considerably diluted, and no doubt was essentially a boiler water analysis.

5. We compute:

Cl	2.694	per thousand
Na	.763	
Ca	.784	
Mg	.056	
K	.077	
Fe	.012	
Al	.016	
Si	.134	
CO_3	.046	
SO_4	.213	
Organic	.027	
Sum	4.827	

Na : Cl . .283

It comes from the same general lode and horizon as the Quincy mine waters analyzed by Koenig, Fernekes and Steiger below, and the water from seams in the Franklin Junior crosscut (analyses 86-88) is also from geologically a similar horizon and depth. The relatively greater amount of sodium as compared with them is marked.

G. A. KOENIG, ANALYST.

6. Tamarack Pond. The next analyses made may have been some by G. L. Heath, of the Calumet & Hecla mine water, but I will first give tests by Dr. G. A. Koenig of the water of the Tamarack mine, as it contaminated the pond from which the boiler water was taken. There is an error in copying the figures below, probably in the calcium carbonate, and the original figures cannot be found. The water was white, opalescent, neutral, boiling gives a white precipitate and the reaction becomes alkaline.

	Total	.79544 per thousand
(CO_2 as)	$CaCO_3$	.254
	$CaCl_2$	.19564
	$MgCl_2$	.0608
	SiO_2	.0215
	NaCl	.2603
	Na_2SO_4	.0242
	Sum	.81644
	Organic matter	p. n. d.
	Bromine	p. n. d.

This may be computed as:

Cl	.33990	
Na	.08904	
Ca	.17073	? Probably .15073
Mg	.02408	
SiO_2	.02150	
CO_3	.15384	?
SO_4	.01635	
Sum	.81544	
	.79544	
Na : Cl	.264	

In this pond water the deep mine water is diluted with surface water rich in lime carbonate but not in sodium silicate as is the case in analyses 4 and 5, where it is diluted with the upper level mine waters. The kind of water which is thus diluted as is shown by Wilson's analysis 22.

7. Quincy Mine. Dr. Koenig made some tests on a deep water from the 47th level of the Quincy running into a sump on the 50th level, given in our annual report for 1903, p. 243, as follows:

Sp. Gr.	1.1898
$CaCl_2$	179.1 per thousand
NaCl	29.6*
$MgCl_2$	0
SO_3	0
CO_2	0

*Misprinted 2.96 in the 1903 annual report, p. 243.

Fe	.004
Cu	.009

The Sp. Gr. would indicate 216.27 grams per kilo of $CaCl_2$. We may compute this as:

Cl	132.5
Na	11.7
Ca	64.5
	208.7

Na : Cl .0885.

This is essentially the same as the water obtained by G. Fernekes from the pump at the 62nd level, and as tested by Geo. E. Steiger, U. S. G. S. Bull. 330, p. 144, and the discrepancies are due to the difficulty of determining small quantities of other things beside such large quantities of calcium chloride. After running along the level the copper dropped to 7 grams per ton.

8. Freda. Dr. Koenig also made some tests of the water of a deep well put down at Freda by the Copper Range Co., which, with the record of the well, are given in the 1903 annual report. It is worth remembering that this is by the side of Lake Superior, five or six miles from the traps of the main copper range in the formation which I have concluded to call the Freda sandstone, the western sandstones of some writers, the Upper Keweenawan of Irving. The well all the way down was in red sandstones, red clays, and fine grained conglomerates, with a good proportion not only of felsites but of grains of more basic rocks. Computing the figures in ions we have:

Cl	40.42
Na	7.60
Ca	16.04
Mn	.57
Mg	.03
K	.30
Br	.21 to .35*
	65.17

Na : Cl .173.

*Midland Chemical Co.

It is worth noting that the much deeper wells at Lake Linden in the eastern sandstone are not reported to have struck any salt water and the analyses (1903 report, pp. 163-164), show only a few, 52.69 parts per million of salt (sodium chloride). It is said, however, that the 1200′ well at Grand Marais struck salt water. A well at Pickford put down in 1907, which reaches down into the Potsdam sandstone and has a heavy flow of water below 1,000 feet, probably at about 1,400 feet, has only .307 of Cl with .9649 mineral constituents.

Other tests of shallow mine waters mixed with surface waters, etc., by Dr. G. A. Koenig are also given in the report for 1903:

9. Winona mine, (annual for 1903, p. 146).

10. Clark mine (annual for 1903, p. 143).

11. Portage Lake water (annual for 1903, p. 144).

This lake receives the drainage of the Quincy and other mines. Compare 31 and 32.

Other well water tests by him, and surface waters are given there.

12. Arcadian shaft (annual report for 1903, p. 243), analyzed Aug. 23, 1898. The shaft was probably not over 250′ deep.

ANALYSES BY G. L. HEATH.

Through the courtesy of the Calumet & Hecla officers I can cite various analyses by the chemist, most of them already published in previous reports.

13. In the annual report for 1903, pp. 143, 163, 164 are a number of analyses of waters from the sandstone around Lake Linden, the strongest of them only .1842 grams per liter. The deepest well was 1,500 feet. Mr. G. L. Heath writes that "no salt water was ever found in it, the well is now filled up several hundred feet so that they are pumping from the upper 500 feet".

"I think that the 1,500-foot well never did furnish much of the supply from the bottom".

14. In the report for 1903 (p. 166) is also an analysis of

the water from the vertical, the Red Jacket (or "Whiting") shaft of the Calumet & Hecla Mining Co. A partial section of this shaft from the company officials is given in Volume V of our reports, which shows its general relation to the Calumet & Hecla conglomerate. It has been continued, and passes through the same at 3,287 feet, down to 4,960 feet. The upper water is so far as possible cased out although there is more or less dripping, and the remaining water is so little that it needs no pump, but can be handled by a tank car, which automatically dumps the water at the top of the shaft. These salt waters are also hard on pumps so that the use of bailers has more than one advantage.

No doubt a good part of the water comes through the lining of the shaft, for as Heath remarks* "the water pumped from the Hecla end of the mine at much less depth is even more saline—from above the 24th level it is bad.

Capt. J. Pollard has shown me cubes of salt from the 9th level, several mm. in diameter, probably due to the slow oozing out and evaporation of the salt water.

The Tamarack No. 3 shaft, Volume V, Part 1, shows "salt water at 1,267 feet" so that the water from the Whiting and similar vertical shafts must not be ascribed to any one horizon.

Mine water, C. & H. vertical shaft. Details of probable composition:

	Grains per U. S. gallon.
Insoluble silica— in sediment	1.29
Insoluble oxide of iron—in sediment	.74
Dissolved silica (SiO_2)	.19
Dissolved chloride of iron	.26
Zinc chloride (with trace nickel)	1.69
Copper chloride ($CuCl_2$)	.26
Magnesium chloride	5.10
Sodium chloride (salt)	109.37
Potassium chloride	4.31
Calcium chloride	182.87
Calcium sulphate	3.23

*Letter, Feb. 22, 1904.

Calcium carbonate (dissolved by free carbonic acid) 14.46
Loss on ignition (actual determination)......... 63.0
No lithium. Undetermined balance, traces carbon, etc.

Sum of all constituents 386.77

"Total solids" on evaporation as weighed. (383+) (354+) 368.5+

G. L. HEATH.

The water was slightly alkaline, and owing to difficulty in weighing a hygroscopic brine residue like this Mr. Heath thinks the sum of constituents as reliable as total solids, since it is impossible to drive off the water without volatilizing other things.

Comment and computations.

The amount of calcium carbonate is nearly that of saturation with the bicarbonate. Bromine and fluorine were not determined.

14. We compute:

Cl	3.2632
Na	1.740
Ca	1.2496
Mg	.0216
K	.0388
Fe	.0026
Cu	.0029
Zn	.0134
CO_3	.149+
SO_4	.0392

Na : Cl .543.

The amount of sodium is relatively very high.

15. A stronger but yet mixed water derived by tapping the water that had accumulated in the Tamarack Junior mine is given by Mr. G. L. Heath, July 27, 1905.

The original figures are:

Sediment (over ½ iron oxide).. .03630 grams per kilo

In clear water:

Silica	.0062
Copper chloride	.0022
Ferrous chloride	.0094

Zinc chloride	.0016
Magnesium chloride	.0346
Calcium sulphate	.0011
Calcium carbonate	.1409
Calcium chloride	8.0912
Strontium chloride	.03152
Lithium chloride	.0038
Potassium chloride	.01174
Potassium bromide	.04736
Sodium chloride	1.9687
Sum	10.38662
Organic matter by diff.	1.3643
Total solids	11.7509

Direct approximate test: organic matter by loss on ignition of solids at redness............ 1.328

Comment and Computation.

The very small amount of sulphate is noteworthy, and the presence of strontium may be connected with it, for strontium sulphate is but very slightly soluble in salt solutions.

Very rarely barite (and celestite?) are found in the Calumet mine.

15. We may compute:

Cl	6.421
Na	0.776
Ca	2.875
Mg	.009
K	.019
Fe	.006
Cu	.00144
Zn	.00076
Sr	.01742
Li	.00063
CO_4	.084
SO_4	.001

Na : Cl .121.
Ca : Cl .448

The sodium is lower. The Tamarack Junior was not rich.

16. Calumet and Hecla 3,000 feet.

None of the above analyses represent the lower mine water of the Calumet & Hecla. They merely represent the upper mine waters more or less contaminated with the lower. The following test is entirely different being of a sample taken for Prof. H. L. Smyth of Harvard, at 3,000 feet depth, vertical probably. Analysis made by Robert Forsyth. The figures are:

66.94 grams per liter solids of which—

Ca	24.77
Mg	0.06
Na	12.14
Cl	61.97
SO_4	0.22
$Si\ O_2$	0.09
Br	.15
Al	.17
	99.57

16. Assuming a Sp. Gr. of 1.05 we should find:

Total solids	63.80
Cl	39.6
Na	7.8
Ca	15.9
Mg	.04
SO_4	.14
$Si\ O_2$	.06
Br	.10
Al	.11
Sum	63.75

Na : Cl .199.
Ca : Cl .403.

ANALYSES BY F. B. WILSON.

When I came to prepare for my 1903 report my paper on the deposition of copper the distribution and chemical character of these mine waters assumed an importance for me that it had not heretofore and I made up my mind to make some personal tests and obtain samples.

The first mine visited was the Wolverine. This is on the

Kearsarge lode, an amygdaloid which dips 40°-41°, but there have been a number of exploratory crosscuts. The Sp. Gr. of the water (at 48° F.) in the

17. 8th level crosscut was 1,000 by urinometer.

18. 13th level crosscut was 1,000 by urinometer.

19. 17th level crosscut was 1,017 by urinometer.

19. The sample from the 17th level was tested by F. B. Wilson with the following results:

Sp. Gr.	1.022	
Cl	15.2287	grams per liter
Na	2.731	
Ca	6.300	
Mg	.013	
SO_4	.0724	
Sum	24.3451	

We may compute this

Na : Cl	.181
NaCl	6.920
$CaCl_2$	17.280
$MgCl_2$	.049
Ca SO_4	.149
Total	24.398

This total agrees with the Sp. Gr. which I found.

This agrees pretty closely with Fernekes' tests at the 20th level south, Wolverine No. 3.

20. 24th level in lode (possibly some water working down through the slopes) 1.012 by urinometer.

21. 29th level crosscut was 1.033.

A some months later test (it may have evaporated) 1.041.

Drops of water from the 17th and 29th levels (19) left to dry seemed to show the water of the 17th level to have rhombs of carbonate ($CaCO_3$) and cubes of salt more conspicuous and abundant. The 17th level water seemed (21) to show gypsum crystals, the 29th crystals with parallel extinction that might? be anhydrite.

The residue from drop of water from the 29th level was notably more hygroscopic and deliquescent.

The behavior agrees with what was found by Fernekes, comparing the 20th and 26th levels.

22. Tamarack mine, Osceola lode.

Later that year in collecting the samples from the 30th level crosscut of Tamarack in connection with President McNair's gravity work, I had a good chance to get a sample from that depth. The results are as follows:

22. Water from Tamarack mine, 4,300 feet down at 1,794-1,800 feet from shaft No. 2. Taken by A. C. Lane, Sept. 14, 1905. Analyzed by F. B. Wilson—letters of Oct. 8, 9, 28 and Nov. 22.

Wilson's determinations.

Sp. Gr.	1.135	
Total solids at their melting point	157,411.5	per million grams per ton parts
Cl	97,963	
Ca	47,166	
Mg	tr	
CO_3	0	
Ba & Sr by flame test on precipitate	0	
Na	8,278	
K	837	
SO_4	226	
NH_4 Cl by distillation	2,456.7	

Whence we may compute (A. C. L.)—Na : Cl =.085.

NH_4	829.8
Total determined solids	155,299.8
Undetermined (organic matter crystal water traces of Fe, Mg, etc).	2,111.7

Which may be combined as

Ca Cl_2	130,508	requiring 83,436 Cl_2
Ca SO_4	320	

Na Cl	21,009	requiring	12,731 Cl
K Cl	1,595		758
NH_4 Cl	2,457		1,627
	156,478		98,552
Excess of salts, shortage of Cl, perhaps replaced by organic acids	1.169		.589

Organic matter leaves a small residue of carbon in the total solids.

The Sp. Gr. agrees quite well with the total solids. The ratios are:

Na : Cl .0846
Ca : Cl .482

A ratio of Na : Cl like this (compare Wolverine No. 3 shaft at the 30th level S.) seems to be that normal to the deep waters.

This analysis has been cited by me in discussing the chemical evolution of the ocean.*

23. I also made urinometer tests of the waters at other points in the 29th and 30th level crosscuts but in every case noted they were stronger than 1.060 the limit of the urinometer scale. In particular is this true of water dripping from a winze up to the 29th level, about 400 feet from No. 2 shaft, which seemed to be between 1.08 and 1.16.

24. As reported in Volume V in the Tamarack No. 3 shaft salt water was struck at 1,267 feet depth, about the horizon of the Quincy lode,[1] in an amygdaloid horizon much above the C. & H.

25. One of the specimens, too, from Tamarack shaft No. 4 from an ophite close above the Calumet & Hecla conglomerate—No. 16,472,]4b72, though kept in our collection from 1894 to 1906 was still damp and bitter with calcium chloride.

*Jour. Geol. XIV (1906) p. 221, Bull. G. S. A. XVII (1906).

1 Annual report for 1903, p. 258.

In fact I believe that President McNair has found this feature a serious difficulty in obtaining specific gravities very accurately.

26. Osceola mine. As No. 22 comes between the Osceola amygdaloid and Calumet & Hecla conglomerate, we may here note that Prof. James Fisher of the M. C. M., reports salty water that was popularly supposed to be depositing copper at the 26th level of the Osceola, following down the foot.

30. Challenge mine. The Challenge mine at the 3rd level at about 700 feet from the surface is distinctly saline. Mr. F. B. Wilson found Ca .232 per thousand which is more than in the ordinary hard water, while the field assay outfit gave me Cl 3.480 about.

Later tests show even stronger waters in a crosscut at this level.

The index of refraction is also distinctly greater than that of pure water, and corresponds to a specific gravity somewhere about 1.015. The sample was not, however, so taken as to be free from possibility of urine contamination.

BOILER WATERS.

Before passing to the chief suite of analyses, that of Dr. G. Fernekes, it will be well to introduce for comparison a group of boiler water analyses from W. A. Converse, of the Dearborn Drug & Chemical Works.

31. Is of Portage Lake at the Isle Royale mill, contaminated both with mine water and sewage. Compare II.

32. At the Franklin mill, of the same body of water. They are both in a wider part of the lake and a little more dilute than the samples tested by Koenig.*

33. Mass creek and mine. Taken while the mine water was yet fresh. Compare Frapwell's analyses (46, 50 53, 55), from the Mass mine.

34. Michigan Copper Mining Co., Rockland Spring is a typical water of the drift or upper levels. One would expect, however, with so much sodium carbonate more silica.

*Annual for 1903, p. 144.

35. Osceola stamp mill creek, contaminated but probably not with mine water as the lime does not go up.

36. Creek at Painesdale (near Champion mine). Has the normal amount of chlorides; no mine contamination.

37. Creek at Tri-mountain, very much like 36, typical surface waters.

38 and 39. Atlantic mine boiler water, a very similar surface water. The higher amount of chlorides is probably due to organic pollution.

40. The Salmon Trout river at Baltic mill is another surface water just like 36 and 37.

41. Spring near Quincy mill; is very low in hardness; reminds one of the sandstone waters, and is over the eastern sandstone; a rain water; the contamination is probably surface.

42. Pond at Allouez mine; very soft; surface contamination.

43. Creek at Mohawk mine.

44. Tobacco river, March 27, 1903.

45. Tobacco river, April 6, 1904.

Compare 44 and 45 with Koenig's analyses of Tobacco river annual for 1903, p. 145.

These are not mine waters and are only introduced here to show what the mine waters would be if they were mainly made up of these surface waters and to show practically what may be expected by using surface waters instead. The normal analysis of a surface water is obviously:

Ca	19	
Mg	4	
Cl	3.5+	if contaminated.
Na	2.3+	if contaminated.
SiO_2	10.	
CO_3	40 +	
SO_4	6 +	
$(FeAl)_2\ O_3$	1.5	
Sum	86.3	per million.

BOILER WATER ANALYSES, DEARBORN DRUG & CHEMICAL CO.,, CHICAGO, ILL.

ALL ARE IN GRAINS PER GALLON.

	31.	32.	33.	34.	35.	36.	37.
SiO_2	.537	.408	.846	.204	.607	.846	.782
$(FeAl)_2O_3$	.152	.151	.233	.321	.023	.152	.035
$CaCO_3$	2.192	2.709	1.880	2.803	4.147	2.920	2.826
$CaSO_4$	.664	trace	trace	trace	.166	trace	trace
$MgCO_3$	.756	.725	.398	.442	1.592	.973	.924
$(NaK)_2SO_4$	trace	trace	1.628	....	....	trace	trace
$(NaK)_2CO_3$	....	....	....	7.255	....	....	....
(NaK) Cl	1.014	1.352	.338	1.005	8.160	.338	.338
Loss, etc	.174	.145	.167	....	.138	.027	.235
Min. Sol.	5.489	5.490	5.490	12.030	14.833	5.256	5.140
Org. matter	trace	trace	trace	.818	.701	....	.584

31. Specimen of water, marked "Portage Lake," received from Isle Royale Stamp Mill, Houghton, Michigan. Feb. 7, '03.

32. Specimen of water, marked "Portage Lake," received from Franklin Mining Co.'s Mills, Pointe Mills, Michigan. Feb. 13, '03.

33. Specimen of water, marked "Creek & Mine," received from Mass Cons. Mining Co., Mass City, Michigan. May 23, '03.

34. Specimen of water, marked "Spring," received from Michigan Copper Mining Co., Rockland, Michigan. April, 1899.

35. Specimen of water, marked "Creek," received from Osceola Stamp Mills, South Lake Linden, Michigan. July 17, '02.

36. Specimen of water, marked "Creek," received from Copper Range Mining Co., Champion mine, Painesdale, Michigan. Feb. 25, '03.

37. Specimen of water, marked "Creek," received from Tri-Mountain Mining Co., Tri-Mountain, Houghton Co., Michigan. Jan. 23, '03.

ALL IN GRAINS PER GALLON.

	38.	39.	40.	41.	42.	43.	44.	45
SiO_2	.630	.584	.642	.642	.233	.478	.508	.513
$(FeAl)_2O_3$	.093	.081	.088	.082	.075	.327	.087	.648
$CaCO_3$	2.239	1.925	2.576	.882	1.068	2.253	1.798	....
$CaSO_4$	.664	.996	.332	.498	trace	.796	trace	....
$MgCO_3$	.898	.949	.721	.570	.455	.681	.628	....
$(NaK)_2SO_4$	trace	trace	trace	trace	trace	trace	trace	....
(NaK) Cl	.676	.338	.338	.676	.676	1.352	.660	.338
CaO........ .								.520
MgO............								.157
SO_3............								.113
Loss, etc	.056	.032	.091	.037	.062	.186	.056	.047
Min. solids	5.256	4.906	4.788	3.387	2.569	6.073	3.737	2.336
Oil & Organic matter	trace	trace	trace	.467	.467	10.512	trace	2.803
Suspended						1.752		1.168

38. Specimen of water, marked "Creek or Dam," received from Atlantic Min. Co., Atlantic Mine, Houghton Co., Michigan, Feb. 27-03. Contains a little less than 5½ grains of mineral matter and a trace of organic matter, per U. S. gallon.

39. Specimen of of water, marked "From creek after passing through heater," received from Atlantic Min. Co., Atlantic Mine, Mich., Feb. 27-03. Contains nearly 5 grains of mineral matter and a trace of oil and organic matter, per U. S. gallon.

40. Specimen of water, marked "Salmon Trout River" (after passing heater,) received from Baltic Stamp Mill, Redridge, Mich., March 18-03. Contains a little less than 5 grains of mineral matter and trace of oil and organic matter, per U. S. gallon.

41. Specimen of watter, marked "Spring after passing through heater," received from Quincy Stamp Mills, Mason, Houghton Co., Mich., Jan. 26-03. Contains a little less than 3½ grains of mineral matter and a small amount of oil and organic matter, per U. S. gallon.

42. Specimen of water, marked "Pumped from mine into pond," received from Allouez Min. Co., Calumet, Mich., April 27-03. Contains a trifle over 2½ grains of mineral matter and a small amount of organic matter, per U. S. gallon.

43. Specimen of water, marked "Mixture of creek and mine" (taken from heater,) received from Mohawk Min. Co., Mohawk, Mich., April 16-03. Contains a trifle over 6 grains of organic matter in solution and a little less than two grains of solid matter in suspension, per U. S. gallon.

44. Specimen of water, marked "Tobacco River," received from Wolverine and Mohawk Stamp Mills, Houghton, Mich., April 6-04. Contains a little over 3½ grains of mineral matter and a trace of organic matter, per U. S. gallon.

45. Specimen of water, marked "Tobacco River" received from Wolverine Copper Min. Co. Mills, Gay Sta., Mohawk, Mich., March 27-03. Contains a little over 2 grains of mineral matter, a little less than 3 grains of organic matter in solution, and a trifle over 1 grain of solid matter (principally organic) in suspension, per U. S. gallon.

SURFACE WATERS OF KEWEENAW RANGE.*

	31. Isle Royale Portage Lake.	32. Franklin Mills.	33. Mass Creek and Mine.	34. Michigan C. M. Rockland Springs.	35. Osceola Stamp Mill Creek.	36. Painesdale Creek.	37. Tri-mountain.	38. Atlantic.	39. After Heating.
Ca	18.3	18.6	12.9	19.2	29.2	20.0	19.4	18.7	18.2
Mg	3.8	3.6	2.0	2.2	8.	4.8	4.6	4.5	4.7
Na	6.8	9.1	11.3	60.9	55.	2.2	2.3	4.5	2.3
K									
Fe Al O_3	2.6	2.6	4.0	5.5	.4	2.6	.6	1.6	1.4
SiO_2	9.2	7.0	14.5	3.5	10.4	14.5	13.4	10.8	10.
Organic		tr.	tr.	(14)b	(12)b		(10)b	tr.	tr.
SO_4	8.0	tr.	18.8	tr.	62.	42.	40.4	4.	31.4
CO_3	31.8	36.7	24.2	104.8	2.	tr.		8.0	12.
Cl	10.5	(a) 14. (a)	3.5		84.5	3.5	3.5	7.	3.5
Loss		2.4	2.8		2.4	.4	4.	.9	.5
Sum	94	94	94	206.5	255.9	90	88.2	90	

(a) Contaminated by Quincy mine water and sewage of Houghton, Hancock and Dollar Bay.
(b) Not included in summation.
(c) 130 parts per million suspended.
(d) 20 parts per million suspended. Oxygen with Mg and Ca 3.6, organic acids combined with bases instead of CO_2 and the sample is acid.

* Boiler water analyses by Dearborn Chemical Works, Chicago. Compare with 11 and 12, Annual for 1903, p. 144; 24 and 25, 145; compare with 22, analyses of Boston pond at the Franklin Junior; analyses p. 146; compare with 14, Annual for 1903, p. 163; compare with the upper mine waters, Annual for 1903, pp. 135-157.

SURFACE WATERS OF THE KEWEENAW RANGE.*

	40. Baltic Salmon Trout River.	41. Quincy Mill Spring.	42. Allouez Mine Pond.	43. Creek and Mine Mohawk.	44. Tobacco River March 27, 1903.	45. Tobacco River April 6, 1904.
Ca	19.3	8.6	6.9	19.4	6.4	12.3
Mg	3.6	2.8	2.3	3.4	1.6	3.1
Na	2.3	4.5	4.6	9.1	2.3	4.4
K						
Fe Al O_3	1.5	1.4	1.3	5.6	11.1	1.5
SiO_2	11.	11.	4.	8.2	8.8	8.7
Organic	tr.	(8)b		(180)b	(48)b	
CO_3	35.2	16.1	16.6	31.4	?	261
SO_4	4.0	6.0	tr.	tr.	2.3	tr.
Cl	3.5	7.0	7.0	14.0	3.5	6.9
Loss	1.6	.6	1.1	3.2	.8	1.0
Sum	82	58	43.8	103.8(c)	(40)d	64

(a) Contaminated by Quincy mine water and sewage of Houghton, Hancock and Dollar Bay.

(b) Not included in summation.

(c) 130 parts per million suspended.

(d) 20 parts per million suspended. Oxygen with Mg and Ca 3.6, organic acids combined with bases instead of CO_2 and the sample is acid.

TESTS BY A. P. FRAPWELL.

Mr. A. P. Frapwell, assistant in chemistry at Ann Arbor, 1906-7, was with us in the summer, and I had him make the tests of the following table with the field assay outfit. They are arranged in the table according to decreasing amount of chloride. The Ca runs from 19 to 60, though the results are not very reliable. The same comment applies to SO_4 determinations, as the electric cells were old. Still that would tend to give SO_4 too high, and we may be sure that SO_4 is at least as low as the low figures shown. Of these waters Nos. 52, 53, 57, 58, 59, 60, 61, 63, and 64 are surface waters and it will be

*Boiler water analyses by Dearborn Chemical Works, Chicago.
Compare with 11 and 12, Annual for 1903, p. 144.
24 and 25, 145.
Compare with 22, Analyses of Boston pond at the Franklin Junior.
Analyses of Boston pond at the Franklin Junior, p. 146.
Compare with 14, Annual for 1903, p. 163.
Compare with upper mine waters, Annual for 1903, pp. 135-157.

noticed that while 52 to 53 are probably contaminated and have 19 and 12 parts per million chlorine the rest have from 3 to 6 parts of Cl. The tests were made in August.

46. Mass mine. Water from seam on 17th level is a typical lower water. This is the only one that showed an increase in Sp. Gr. which according to Frapwell was (? on 18th level) 1.041 by urinometer, or about 5% solids. Compare with No. 50 and note that down to the 10th level it is fresh.

47. This was a sample sent in by Mr. Dennis from the Rhode Island mine on the Allouez conglomerate, at the 1,000′ level. This was also tested by Fernekes just as he was leaving and pronounced fresh. This is the same lode as the Franklin Junior is working and is about the same strength as that at the 7th level according to Fernekes.

48. This water flows from diamond drill hole No. 5 of the Belt mine. It is 3,680 feet S. and 1,960 feet E. of the N. quarter post of Sec. 31, T. 51, R. 37, in a swamp 408′ above Lake Superior. It was put down at an angle of 62° 26′ and it was 127′ to bed rock, i. e. 112 feet vertical. The presence of sodium carbonate and its softness are noticeable. It flows nearly one cubic foot per minute at a temperature of 45° F. A similar water comes from a Calumet and Hecla drill hole. The conditions are favorable for a flow (see cross section Fig. 1), as the dip is to the north and there is a hill to the south. Taking the temperature and all considerations together, it is probable that the water comes in not below 5,207 feet of drill hole or 180 feet vertically, and it is interesting as showing how close to the surface the saline water comes where the hydrostatic pressure is upward, even though shielded by drift from active circulation and with no great depth of circulation.

49. The water of the Michigan mine, B shaft, down to the 10th level inclusive, as pumped to surface. One is tempted to believe that there was also some turbidity here as well as in No. 51 counted in the sulphates.

50. The water of Mass mine, C shaft, for the first thousand feet, down to and including the 8th level.

51. Adventure Mining Co., No. 4 shaft, water as pumped down to the 8th level inclusive. This shows a little greater strength than No. 54.

52. Rockland town pump, depth 25 feet. The chlorine here is possibly due to sewage contamination.

53. Mass mine hospital well. The chlorine here is also, possibly sewage contamination, though very likely not recent.

54. Adventure mine No. 1 shaft, water down to and including the 6th level.

55. Mass mine, A shaft, water from seam in 10th level.

56. Adventure mine, No. 3 shaft, water as pumped down to and including 12th level.

Taking such analyses as 54, 55, and 56, it is obvious that they are as good boiler water practically as the surface waters, and that 53 may have contained a good deal of mine water. Analyses 49, 50 and 51 begin to show contamination with chlorine, but on the whole the water is very fresh. Comparing them with drill hole water No. 48 we see the difference produced by the topography, for the latter is in a valley in the rock surface, while the Mass, Michigan and Adventure mines are beneath high ground, on the sides of hills that rise a couple of hundred feet above the general level and 500 or 600 feet at least above the valleys of the rock surface.

57. Greenland town pump, depth 25 feet, in the center of the town surrounded by houses.

58. Well at carriage barn, Michigan mine.

59. Boarding house well at Adventure.

60. Surface spring top of Knowlton Hill.

61. C. R. R. tank, near Belt station, surface springs on south front of Aztee hill, Sec. 31, T. 51 N., R. 37 E.

62. This was sent in by Mr. Dennis from the Rhode Island mine from a diamond drill hole into the hanging of the Pewabic lode, and should be compared with tests at the Quincy and Franklin Junior mines.

63. Well at dwelling house on a farm at Riddle Junction. This is in the drift in lake clays, and N. B. not marine clays.

64. Spring near top of Flint Steel hill near road. This is practically a surface water having no great depth.

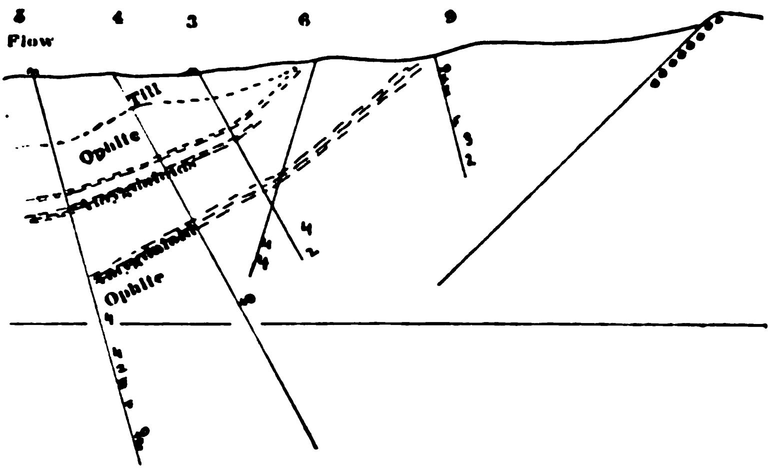

FIGURE I. Cross section at Lake Copper Company, illustrating the flow at drill hole 5.

	Cl.	SO_4	Total Hardness		Alkalinity			Alkalinity			Total CO_3
				as Ca	$CaCO_3$	Ca	det CO_3	Na_2CO_3	Na_2	det CO_3	
46	22476	135	109	44	15	6	9	21	9	12	21
47	760	Not determined									
48	264	82	61	24	25	10	15	32	14	18	33
49	58	120	123	49	340	136	204	0			204
50	30	110	82	33	263	105	158	0			158
51	20	foot note *	113	45	187	75	112	0			112
52	19	less than 20	133	53	165	66	99	0			99
53	12	" "	205	82	341	136	205	0			205
54	7	" "	48	19	195	78	117	0			117
55	6	38	41	16	225	100	125	0			125
56	6	less than 20	123	43	175	70	105	0			105
57	6	" "	96	38	146	58	88	0			88
58	5	" "	82	33	75	30	45	0			45
59	5	" "	92	37	120	48	72	0			72
60	4	" "	48	19	59	24	35	0			35
61	4	" "	116	46	147	60	87	0			87
62 x	3	Not determined									
63	3	" "	150	60	213	85	128	0			128
64	3	" "	48	19	48	19	29	0			29

*The SO_4 determination was not accepted, as the water was very heavily charged with suspended matter.

In the case of the 1st and 3rd determinations, if $CaCl_2$ were present, the dissociation theory might account for the abnormal results obtained in the tests for carbonates.

The springs at top of Knowlton and Flint Steel Hills are on the road from Greenland to Rockland. When the water is said to come from more than one level, the tests were made on the water after it was pumped to surface.

xDrill hole, northwest into hanging.

The amounts are in milligrams per liter.

The methods are those of U. S. water supply paper, No. 151, Field Assay of Water.

DR. G. FERNEKES' ANALYSES.

In talking over the matter with Dr. G. Fernekes, of the chemical department of the College of Mines, he expressed a very keen interest and willingness to take the matter up more systematically. His experiments in reproducing copper were his own free contribution to the advancement of science, and he also made a series of tests of mine waters, which went far beyond what he was paid for.

In all cases chlorine, calcium and total solids were determined. In many cases computing sodium enough to satisfy the acid, made solids enough by summation very nearly to agree with those obtained by "heating to incipient fusion", which latter is the way the total solids were determined for the lower stronger waters. This gave results a "little too low" as "some of the calcium chloride was broken up". This method was not employed for the upper waters that might contain large proportions of carbonates. In a number of cases other substances were determined, the bromine most commonly. In a few cases exhaustive tests were made, and tests for copper and nickel more widely. Iron and alumina were measurable in the Quincy waters.

The results are in grams per liter, oz. per cubic foot. Sp.

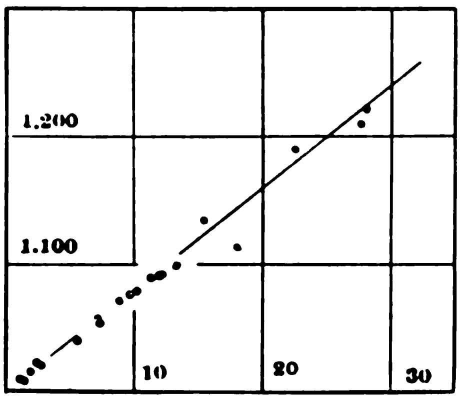

FIGURE II.

Gr. was determined for about a dozen of the waters. As is shown by figure it pretty closely follows the rule that ten eighths of the excess of Sp. Gr. is the proportion of total solids. The NH_3 was not titrated but distilled. Distillation tests failed to detect ammonia generally.

Connecting the Sp. Gr. and the total solids the percentages are represented by abscissas from left to right, the specific gravity by ordinates. The total solids as here given therefore will not include organic matter or ammonia, or a very small amount of the chlorine perhaps, but the moment we try to include them in the total solids we find ourselves also including more or less crystal water

TESTS OF THE BALTIC LODE.

This is the lowest of the lodes. It lies between a conglomerate (the Baltic conglomerate) as it is generally called (No. 3) and a heavy ophite, known as the Mabb ophite, whose mottles are up to 7 mm. across. The distance above the conglomerate varies, but is about (150) feet more or less, and it is 170 to 200 feet below the ophite. It is no one well defined amygdaloid top to a flow but rather an impregnated shear zone or stock werk, copper being found over a belt more than 40 feet wide.

Besides Fernekes' tests see other tests and reports from the Baltic, Trimountain, Champion and Challenge shafts. (130-133).

65. Trimountain. On a visit to the Trimountain mine of the Copper Range Company, Sept. 4, 1906, I took a sample of salt water from 200 feet N. of shaft No. 3 S. 9th level in a lean streak of rock that comes under a cross seam which dips about 45° to the south.

The Sp. Gr. as estimated in the mine was 1.078 at the mine temperature, probably about 51° F.

Dr. Fernekes found, Sept. 8, 1906.

Sp. Gr.	1.053	(= 65.8 $CaCl_2$)
Total solids	74.44	parts per thousand
Cl	46.02	
Na	3.36	
Ca	24.58	

SO_3	.484
Fe, Mg, CO_2	tr.
Sum	74.444

We may compute:

NaCl	8.54
$CaCl_2$	63.90
$CaSO_4$	.823
Excess of Ca combined with CO_2 in part	1.28
	74.543

Na : Cl .076
Ca : Cl .535

A larger sample taken for and tested by Dr. Fernekes was much less strong (perhaps this latter was of the water of the drift as a whole) as follows:

66. Trimountain 9th level.

Cl	19.874 per thousand
Ca	9.000
(to satisfy acids) Na	2.653
Br	.243
	31.770
Diff.	.230
Total	32.000

Na : Cl .133
Ca : Cl .453

Both in concentration and proportion of sodium this No. 66 is of a distinctly higher type than No. 65, but as it was taken later, the water may have run down from a higher level. I have elsewhere noted that salt water was reported from this mine at the 6th level.

The Baltic water appears to be fresher than the Trimountain. The drift covering was much thinner, the bed rock surface higher and the lode on the whole richer.

67. Baltic mine. 15th level. Dr. Fernekes reports:

Cl	27.264
Ca	13.682
Na	1.929

Br 0.3112
Sum 43.187
Difference .... .813 (CO_3 or SO_4)
Total solids 44.000
Na : Cl .073

We may compute:

$CaCl_2$ 38, Cl = ...24.3
$NaCl_2$ 3.79, Cl = ... 2.946
NaBr .402, Br = ... .312
Na_2CO_3..2.3

44.492

—Where the carbonate and sulphate really combine more with the lime.

Franklin Junior. This is the same property formerly known as the Peninsula and earlier yet as the Albany & Boston. It has worked upon two horizons, the one the Pewabic lode, at the same horizon as the Old Franklin and Quincy mines, the other a conglomerate, Marvine's No. 15, which has been called the Albany & Boston, and may be safely identified with the Allouez. Most of the observations refer to the conglomerate but those in the crosscuts, 87 and 88 especially, do not, and should be compared with those of the Pewabic lode. See also Packard's tests on the Franklin water (3, 4 and 5).

68. On a visit May 24th, 1906, I found in the 14th level crosscut 270 feet above the Allouez conglomerate a drip with Sp. Gr. 1.000.

69 and 70. On the 15th and 16th levels I did not find enough water to test. There was more in the north end of the 15th level and the south end was very dry.

71. On the 17th level the water on the floor seemed to have Sp. Gr. 1.000.

72. 400 feet north of shaft it was dripping freely and seemed to have increased in gravity (1.002?).

73. On the 18th level S. a dripping tested had Sp. Gr. 1.000.

74. At the reservoir for drill water near shaft it was 1.003.

75. On the 19th level I could only find a drop to taste—quite salt.

76. The 20th level was dry.

77. The 21st level water of drift has Sp. Gr. 1.003.

78. The change from fresh to salt was according to Capt. J. Doney between 14th and 17th levels and his observation was later fully confirmed by Fernekes' tests. The rock also seems to get richer in the lower part of No. 2 shaft, toward the south end of the mine.

The Allouez conglomerate has a straighter "hanging" top than "foot" bottom, and where it is thin it is generally barren. There is good copper bearing conglomerate in the 22nd level.

The dip flattens from 48½° down to 46¾° at the bottom of the mine.

Mr. Rickard in his book on the copper mines of Lake Superior has some notes on the distribution of copper in this lode.

On Oct. 13, 1906, I again visited the Franklin Junior mine and incidentally made observations as follows:

79. At the fourth level crosscut which runs from the Allouez conglomerate to below the Kearsarge amygdaloid, the water was in no case noted other than apparently fresh. Sp. Gr. 1.000. Temp. 45° to 46° F. We failed to get any at crevices on the 17th and 19th level where Capt. Doney had noticed it. But Fernekes found it later, and I introduce his tests on the conglomerate before those he made from the samples I took on the crosscut at the 21st level.

All the samples below are from the No. 1 shaft, on the Allouez conglomerate, and taken by Fernekes in 1906.

80. Is from a drip in the 15th level.

Cl	416
Ca	134
Na	115
Sum	665
Difference	85
Total solids determined	750

We may compute:

Na : Cl	.277		
Ca : Cl	.322		
NaCl	.292	Cl	.177
$CaCl_2$	.375	Cl	.239
	.667		

The high ratio of sodium to chlorine and of difference not chlorides show the mixture of upper water quite plainly. This is just on the line.

81. Franklin Junior is from a dripping 1,000 feet S. of No. 1 shaft on the Allouez conglomerate, 17th level.

Cl	.858
Ca	.211
Na	.313
Sum	1.382
Difference	.313
Total solids	1.695
Na : Cl	.1382

This seems to be fresher than No. 74 on the same level north. It is said that No. 2 shaft 1200′ S. of No. 1 is better than No. 1 and better than at 1200′ or so than higher up. At the Rhode Island mine which is further north and not so rich Mr. Frapwell found No. 47 about as strong at 1,000 feet.

82. Franklin Junior reservoir 100′ north of No. 1 shaft, 17th level on Allouez.

Cl	1.066
Ca	.249
Na	.404
Sum	1.719
Difference	.281
Total solids	2.000
Na : Cl	.39

83. Franklin Junior water dripping 1200 feet S. of No. 1 shaft on 18th level.

Cl	3.621
Ca	1.516
Na	.609
SO_4	.040
Sum	5.756
Difference	.274
Total solids determined	6.030

This is a *good deal fresher* than the next analysis, the 19th level north.

Na : Cl .167

84. Franklin Junior from a dripping on the 19th level 200 feet north.

Cl	8.320
Ca	3.166
Na	1.750
Sum	13.236
Difference	.224
Total solids determined	13.560

Na : Cl .21

We compute:

Ca Cl_2	8.79
Na Cl	4.45
	13.24

This is essentially the same water as No. 70 of which apparently No. 85 is another test.

85. From pump on 23rd level near bottom of mine.

Cl	7.540
Ca	2.493
Na	2.032
Sum	12.055
Difference	.295
Total solids determined	12.350

This is practically the same as 81 and 82, slightly diluted. The ratio of sodium is similar.

Na : Cl .269

The line between fresh and salt is perhaps higher at the north and leaner end of the mine corresponding to the rise of ground. The depth is something like 1300 feet below the surface or about 200′ below sea level.

86. Franklin Junior. Dripping from crosscut on 21st level S.

Cl	8.580
Ca	3.289
Na	2.349
Sum	14.216
Difference	.044
Total solids determined	14.260

Na : Cl .272

87. Sample No. 1, 2100′ down on the dip, 1600′ deep. The sample is in a crosscut over from the Allouez conglomerate 460′ toward the Pewabic lode on which the Quincy mine is working. It is from a seam dipping 50° to S.E., i. e., about at right angles to dip of bed. It is slowly dripping. The distance from the Allouez conglomerate No. 15 is 192′4 (about 100′ above the Mesnard epidote).

87. Sp. Gr. by urinometer in mine 1.045. Temperature 61° F.

Dr. Fernekes determined (on about 30 cc).

Cl	7.912
Ca	2.926

Whence we may compute:

Na to satisfy Cl	1.764
Sum	12.602
Difference SO_4, Mg. etc	.298
Total solids at 160°C	12.900
Ca Cl_2	8.116

(To satisfy Cl) Na Cl 4.486

12.602

Na : Cl .223

Ca : Cl .368

This agrees quite fairly with the larger sample 86 taken later by Dr. Fernekes himself. I cannot very well account for the high Sp. Gr. of this and 88, unless we assume that the water gave off little bubbles of gas not observed in the dim light of the mine, or that evaporation tends to very rapidly concentrate the water in the puddles on the floor where the urinometer was floated. The sample was caught in a small vial from the roof.

88. Another sample II was flowing much more freely down the side of the level from a similar seam 386 feet above the Allouez conglomerate and dipping 40° into the foot from the hanging. It must pretty nearly represent the Pewabic lode.

Sp. Gr. 1.055.

Dr. Fernekes determined:

Total solids at 160° C...............46.100

Cl 28.680

Ca 12.290

Whence we compute:

(To satisfy chlorine Na).............. 4.45

45.42

Ca Cl_2 ....34.09

Na Cl 11.33

45.42

Other substances by difference, SO_3, Mg., etc.. .68

Na : Cl .156

Ca : Cl .43

QUINCY MINE.

The Quincy mine was of especial interest as offering the deepest mining on the amygdaloid, and as being the one in which copper in the mine water first attracted attention. It was not easy to obtain satisfactory samples in the upper old workings. The tests of the Franklin mine which is on the same lode may be taken in connection (analyses 4 and 5).

I am informed by Prof. J. Fisher that in the Quincy mine flows good to drink were found.

89. On the 13th level.

90. And on the 26th level.

91. But that on the other hand a drill hole in the hanging between shaft 1 and 2 just N. E. of the old man engine shaft on the 26th level was too salt to drink. This is about 2,000 feet deep on this lode, which at a dip of 53° is 1609 feet vertically. This would bring the salt water in at about the same depth as in the Franklin—a little deeper possibly. It should be remembered that the Pewabic lode worked by the Quincy Mining Co. is in the "ashbed" group, a series of extra feldspathic traps containing unusually much sodium.

Certain of the Quincy samples were tested for CO_2 by distillation, and also for ammonia. A very small amount of the latter was found on which no stress can be laid as it might come from organic contamination or dynamite fuses.

92. Dr. Fernekes' first test is from drippings in the 49th level north of No. 6 shaft, as follows:

Cl	142.173 grams per liter
Ca	70.072
Na	12.064
Br	1.891
Cu	tr.*
Sum	226.206
Difference	.320
Total solids determined	226.52

Sp. Gr. 1.19.

Whence we compute:

Na : Cl .083

93. From the 53rd level north of No. 6 shaft running from walls.

*Analyses 89 to 97 all contain a trace of copper estimated as most probably 8 to 16 mg. per liter.

Cl	174.287 grams per liter
Ca	86.500
Na	14.068
Br	2.180
Cu	tr.*
Sum	277.035
Difference	.465
Total solids Determined	277.500**

Sp. Gr. 1.2 1

We compute:

Na : Cl .081

94. Quincy mine. 53rd level N., stream near No. 6 shaft.

Cl	177.380 grams per liter
Ca	87.478
Na	14.920
Cu	trace*
Br	2.240
SO_3	.123
Sum	282.141
Difference	.359
	282.500

We compute:

Na : Cl .0843

This analysis was published by Dr. Fernekes in Economic Geology II, p. 584, with a slight error.

95. Quincy mine. In stope 10 feet below 53rd level N. of No. 6 shaft—a running stream.

Cl	173.735 grams per liter
Ca	87.380
Na	13.470
Br	2.272
Cu	tr.*
Sum	276.857

**Solids when not heated quite so hot 281.900.

Difference	.243
Total solids determined	277.100

We compute:

Na : Cl .078

This sodium ratio is abnormally low—an error in analysis is possible but not probable.

96. Quincy mine. Dripping on 55th level N. of No. 6 shaft.

Cl	176.027	grams per liter
Br	2.200	
Ca	86.478*	
Na	15.188	
K	411	
SO_4	110	
$Si\ O_2$	20	
Fe_2O_3 and Al_2O_3	10	
Mn	4	
Cu	16	
Ni	6	
Sr	trace	
Ba	none	
Li	none	
Mg	20	
B	trace	
CO_2	none	
Sum	280.489	
Difference	.011	
Total solids determined	280.500	

This is the most complete analysis made of the deep water and may be taken as the standard. Nos. 93, 94 and 97 are all very similar. It is worth noting that calcium and sodium chlorides form 99% of the total salts, and sodium bromide three-fourths the remainder.

Na : Cl .0865
Ca : Cl .49

*Compare test of Dow Chemical Co., .17 per cent or 2.13 grams per liter.

97. Quincy mine. N. of No. 6 shaft, running 10 feet below 55th level.

Cl	176.400
Ca	85.200
Na	17.580
Br	2.460
Cu	tr.*
K	.450
Sum	282.090
Difference	.310
Total solids	282.4

Sp. Gr. 1.22

Boiling point 104°.5 C.

We compute:

Na : Cl. .099

This higher ratio of sodium might be due to urine, etc. A sample at about this level gave the Dow Chemical Co., .17% with a Sp. Gr. of 1.293 or 2.190 grams per liter. The same sample gave Fernekes 2.390, which is a pretty close check as bromine analyses go.

98. Quincy mine. Pool with good drainage on 57th level N. of No. 6 shaft.

Cl	113.7	grams per liter
Ca	57.33	
Na	7.70	
Br	1.2	
Sum	179.93	
Difference	.270	
Total solids determined	180.2	

Sp. Gr. 1.13

Na : Cl .068

99. Quincy mine. 59th level, said to be a fine slow drip.

***Trace in all Quincy waters, estimated at 8 to 16 mg. per liter. Compare test (7) of Dr. G. A. Koenig of 7 mg. per liter as running along the drift.**

Cl	166.56
Ca	82.486
Na	13.129
Br	1.92
Sum	264.035
Difference	1.165
	265.2

We compute:

Na : Cl .0785

100. Quincy mine. 62nd level, N. from pump.

Cl	131.46	grams per liter
Ca	65.35	
Na	10.56	
Br	2.004	
Sum	209.374	
Difference	.426	
Total solids determined	209.8	

We compute:

Na : Cl .08

101. In Bulletin 330 of the U. S. Geological Survey, p. 144, is an analysis of the water from the "lower level of the Quincy mine, Hancock, Michigan", by Geo. E. Steiger for C. K. Leith as follows:

	E.	
Cl	635.5	135.
SO_4	.1	.2
CO_3	.1	.2
PO_4	.0	.0
Na	56.3	12.0
Ca	307.8	65.3
Mg	.1	.2
Al, Fe, Mn, Co	.0	
SiO_2	.1	.2
	1000.00	sum 213.1
Salinity	212.3	212.3

Na : Cl .0885

Ca : Cl_2 .485

The column to the right is computed. The analysis is like that of Fernekes (96) from the Quincy from the pump at the 62nd level, but not as complete. The most noteworthy discrepancy is in the CO_2. These Quincy analyses are all of the lower water and show what variation we may be prepared to expect.

The Calumet Conglomerate. See also the analyses by Heath and Smyth. (14-16)

102. Tamarack shaft No. 5. This sample was taken from an inclined winze on the conglomerate lode:

Cl	57.550	grams per liter
Ca	25.429	
Na	8.032	
Br	1.070	
Sum	92.081	
Difference	.419	
Total solids determined	92.500	

We compute:

Na : Cl .14

When we compare this with No. 22 we see that it is less strong and the ratio of Na : Cl is higher. This agrees with the miner's impression reported by Mr. J. C. Reeder and others that amygdaloid water is stronger than that of the conglomerate, which is confirmed by other tests for chlorine only.

It is somewhat stronger than Smyth's water at 3,000 feet (16). The ratio of sodium has dropped a little. The ratio of Na : Br is about the same.

The Kearsarge Lode. This lode is now opened up for several miles, and Dr. Fernekes could get salt tests for over three miles. His results are arranged from south to north.

103. Centennial mine. At the 11th level "no salt" was reported; that is not enough to make the customary analysis on a small sample. Fernekes estimates that a gallon would have been needed.

104. At the 13th level we have:

Cl	1.711
Ca	.626
Na	.389
Sum	2.726
Difference	232
Total solids determined	2.958

We compute:

Na : Cl .228

105. 15th level.

Cl	3.549
Ca	.880
Na	1.287
Sum	5.716
Difference	.264
Total solids determined	6.000

We compute:

Na : Cl .357

This is a typical top salt water, and was published as such in Economic Geology II, p. 584, but assigned to the 11th level.

106. Centennial 20th level.

Cl	5.780
Ca	1.880
Na	1.584
Sum	9.244
Difference	.216
Total solids	9.460

We compute:

Na : Cl .275

The ratio of sodium begins to drop. This analysis was published in part in Economic Geology II, p. 584.

107. Centennial 25th level.

Cl	27.114

Ca	11.6
Na	4.22
Cu	p.n.d.*
Sum	42.934
Difference	.266
Total solids determined	43.200

We compute:

Na : Cl .156

108. Centennial 30th level

Cl	34.263
Ca	15.700
Na	4.140
Cu	p.n.d.*
Sum	54.103
Difference	.377
Total solids determined	54.480

Na : Cl .121

Note that the most rapid rise in saltness comes between the 20th and 25th levels.

109. South Kearsarge No. 2 shaft, 9th level, drippings collected by F. W. McNair and C. D. Hohl.

Cl	.842
Ca	.111
Na	.418
Sum	1.371
Difference	.61
Total solids determined	1.432

This is essentially a duplicate of No. 110. Compare the 10th and 11th levels Mohawk.

Na : Cl .495
Ca : Cl .132

110. South Kearsarge No. 1 shaft, 9th level, dripping collected by F. W. McNair and C. D. Hohl.

*Estimated as 2 to 8 mg. per liter.

Cl	.702
Ca	.0912
Na	.414
SO_4	.075
SiO_2	.035
Fe_2O_3)	.030
Al_2O_3)	
Sum	1.3472
Difference	.0028
Total solids determined	1.350

This is a complete analysis intended to show the character of the water in the upper levels, before the calcium chloride becomes conspicuous, though even here there is chlorine, which may be considered combined with calcium. There is even here little or no CO_2 and the Ca is not abnormal for any water.

Probably the iron and alumina may exist as chloride.

$(Fe_2O_3 = .030) = (Fe = .021)$

We have:

Na : Cl .58
Ca : Cl .13

We may combine this as

Water glass $Na_2O\ 4\ SiO_2$	= .0097+.0034+.035	= 0.048 6
Salt Na Cl	= .4043+.624 Cl	= 1.028 3
Fe Cl_3	= .021 +.039	= .060
	.663	
Ca Cl_2	= .022 +.039	= .061
Ca SO_4	= .0312+.075 SO_4	= .1062
	.0532	
CaO	= .038 +.015 O	= .053
		1.3571

Note the tendency to alkalinity, both in the water glass and the excess of lime, and the sodium more than could be obtained by dilution of a deeper water with a surface water.

Wolverine Mine. Shaft No. 3. All the samples below were taken about 300 feet S. of the shaft, and were all drippings. To get the complete suite include also tests 17 to 21. See also my tests in crosscuts, etc.

111. Wolverine No. 3, 300 feet S. of 20th level.

Cl	17.395
Ca	7.321
Na	2.852
Sum	27.568
Difference (Mg, SO_4, etc)	.252
Total solids determined	27.82

Sp. Gr. 1.021
Na : Cl .165

This is slightly stronger and with slightly less sodium in proportion than No. 19.

112. Wolverine No. 3, 300 feet S. of 22nd level, drip.

Cl	11.705
Ca	5.071
Na	1.784
Sum	18.560
Difference	.800
Total solids determined	19.360

Sp. Gr. 1.015

We compute:

Na : Cl .153

This is apparently somewhat diluted of the same type as the water at the 17th and 20th levels.

113. Wolverine No. 3, 300 feet S. of the 24th level, dripping.

Cl	33.640
Ca	15.600
Na	4.088
Br	.868
SO_4	.130
Sum	54.326

Difference	.174
Total solids determined	54.5

Sp. Gr. 1.039

We compute:

Na : Cl .122

The lowest water is well established. Note as compared with the other levels the sudden rise in solids, almost double, while the sodium ratio drops.

This is about the same concentration as the 30th level, Centennial, No. 108.

114. Wolverine No. 3, 300 feet S. of 26th level, dripping.

Cl	55.765
Ca	26.800
Na	5.912
Br	.930
Sum	89.407
Difference	.393
Total solids determined	89.8

Sp. Gr. 1.071

We compute:

Na : Cl 0.106

115. Wolverine No. 3, drip 300 feet S. on 28th level.

Cl	75.231
Ca	36.347
Na	7.367
Br	1.085
Sum	120.030
Difference	.270
Total solids determined	120.3

Sp. G. 1.092

We compute:

Na : Cl 0.098

116. Wolverine No. 3 shaft, 300 feet S. of 30th level, dripping.

Cl	64.390
Ca	31.271
Na	5.756
Br	.940
Cu	p.n.d.*
Sum	102.357
Difference	.143
Total solids determined	102.5

Sp. Gr. 1.079

Nos. 114, 115 and 116 are nearly the same kind of water varying slightly in concentration and the Na : Cl ratio slowly falling. In this it is:

Na : Cl .0895

The varying concentrations of these deep waters may be partly due to evaporation and partly to very recent circulation of fresh water incident to the mining.

The Centennial 30th level water is about as strong as the Wolverine 24th level water and the Na : Cl ratio is the same.

117. North Kearsarge mine. 26th level, 700 feet S. of No. 3 shaft.

Cl	83.400
Ca	38.667
Na	9.826
Cu	p.n.d.**
Br	.905
Sum	132.798
Difference	.202
Total solids determined	133.000

Sp. Gr. 1.099

Na : Cl .118

This is much stronger than any of the Wolverine waters but the Na : Cl ratio is similar to that on the 26th level.

***Estimated from 2 to 8 mg per liter.**

****All samples from N. Kearsarge contain from 2 to 8 mg per liter of Cu as estimated.**

118. N. Kearsarge, 300 feet S. of No. 3 shaft, on the 27th level.

Cl	71.240
Ca	31.822
Na	9.822
Cu	p.n.d.*
Br	.945
Sum	113.829
Difference	.371
Total solids determined	114.2

Sp. Gr. 1.089

Na : Cl .1375

This is less strong than 119 at the N. end or than No. 117 on the level above, but has just about the same amount of sodium.

119. N. Kearsarge 450 feet N. of No. 3 shaft, 27th level.

Cl	76.363
Ca	32.937
Na	11.597
Cu	p.n.d.*
Br	.725
Sum	121.622
Difference	.178
Total solids determined	121.800

Sp. Gr. 1.091

We compute:

Na : Cl .151

These are running a good deal higher in sodium than the Wolverine at the same levels and concentration.

120. N. Kearsarge, 28th level, 150 feet S.

Cl	60.480
Ca	25.618
Na	9.722
Br	.675
Sum	96.495

Difference	.245
Total solids determined	96.740

Sp. Gr. 1.074

Na : Cl .161

As we go north toward the Allouez Gap the amount of sodium at about the 26th to 28th levels seems to increase.

Mohawk Mine. Shaft No. 1. 10th level dripping.

121.

Cl	.357 grams per liter
Ca	.067
Na	.154
Sum	.578
Difference CO_3, SiO_2, etc.	.122
Total solids determined	.700

Na : Cl .43

This is a typical upper level water like the S. Kearsarge 109, but only half as strong.

122. Mohawk, shaft No. 1, 11th level, dripping.

Cl	.285
Ca	.057
Na	.1198
Sum	.4618
Difference	.1382
Total solids determined	.600

Na : Cl .42

This is essentially like 105. Note how sharp the change is at the next level.

123. Mohawk, shaft No. 1, 12th level, dripping.

Cl	3.172
Ca	.993
Na	.914
Sum	5.079

Difference	.276
Total solids determined	5.355

Na : Cl .294

This is fairly in the middle zone.

124. Mohawk, shaft No. 1, 13th level, pool.

Cl	3.299
Ca	1.241
Na	.711
Sum	5.251
Difference	.349
Total solids determined	5.600

Na : Cl .216

125. Mohawk, shaft No. 1, 20 feet S. of 14th level, dripping.

Cl	21.546 grams per liter
Ca	10.560
Na	1.824
Br	.124
Sum	34.054
Difference	.346
Total solids determined	34.400

Na : Cl .085

This is quite characteristic of the lower zone.

Isle Royale Mine. Arcadian, i. e. Isle Royale amygdaloid epidote, and possibly Grand Portage lodes. This is close to Portage Lake just back of Houghton, and is 400 feet or 500 feet above it, i. e. above Lake Superior. It is the old Huron mine re-opened. This went down about 16 levels or 1000 feet.

On the Grand Portage lode shafts to 500 feet were sunk This opened on many levels by crosscuts, but is about 200 feet (above) west of the Isle Royale lode on which the shaft is sunk.* This is worth mentioning since dripping from the

*N. B This is not on Isle Royale.

levels might well have been affected by surface water standing in the levels a good while. The College of Mines have a list of some 30 minerals from this mine.

126. Isle Royale. 300 feet N. of No. 2 shaft 15th level, dripping.

Cl	9.204 grams per liter
Ca	4.321
Na	.994
Sum	14.519
Difference	.581
Total solids determined	15.1

Sp. Gr. 1.007 low!

We compute:

Na : Cl .0925

This is a dilute deep water.

127. Isle Royale, 18th level, dripping, 300 feet N. of No. 2 shaft.

Cl	34.920
Ca	16.751
Na	3.058
SO_4	.179
Cu	p.n.d.*
Sum	54.908
Difference	.792
Total solids determined	55.70

We compute:

Na : Cl .089

This is a typical dilute deep water.

128. Isle Royale, 19th leevl, N. of No. 2 shaft, from a pool from dripping.

Cl	45.178
Ca	22.201
Na	3.837

*Estimated 2 to 8 mg per liter.

Br	0.320
SO_4	.234
Cu	p.n.d.*
Sum	71.770
Difference	.330
Total solids determined	72.1

Sp. Gr. 1.057

We compute:

Na : Cl .085

129. Isle Royale, dripping 50 feet S. of No. 2 shaft on 20th level.

Cl	7.626
Ca	3.249
Na	1.204
Cu	p.n.d.*
Sum	12.079
Difference	.241
Total solids determined	12.32

Sp. Gr. 1.009

Here is lower down a distinctly weaker water with

Na : Cl .158

The contrast between this and No. 126 is worth noting. Though they have about the same strength the deeper water is in one case diluted with fresh water that has found its way rapidly and directly down, while in the other case there is much sodium, presumably derived by decomposition of the rock.

130. Victoria mine, Rockland district. This is at a low horizon in the formation. The sample was taken by Dr. L. L. Hubbard from the 19th level crosscut, about 600 feet from the shaft in a thin conglomerate underlain by 10 feet of amygdaloid then succeeded by 60 to 70 feet of conglomerate and sandstone, mainly sandstone.

*Estimated 2 to 8 mg per liter.

Sp. Gr. 1.004; Total solids..........6.465 grams per liter
Chlorine..........3.159 grams per liter

A number of less complete tests for chlorine, and other supplementary data are here omitted, since they simply sustain the inferences which may be made from the above data.

ORIGINAL SOURCE OF WATERS CONNATE.

The widespread occurrence of these calcium chloride waters points to an original source, they are connate—original sea waters—modified by downward leaching. It is hardly conceivable that any upward circulation could so fill the Keweenawan rocks with salt water through a set of fissures that *everywhere* below the 21st level the content of salts is to be measured in per cents. And they are by no means confined to the copper and iron countries.

The well at Grand Marais struck, I am told salt water at the bottom, 1200 feet deep, and the Hon. Geo. Shiras 3d, called my attention to a salt lick southeast of Marquette, which gave Mr. F. B. Wilson,

Total solids	2.484 per thousand
Chlorine	.862
Sulphuric anhydride	.008
S. from sulphur anhydride	.027
Calcium and potassium carbonates present, indet. in 25cc.........	
Magnesium	tr.

I have just visited these licks at the south end of Whitefish lake, Sec. 3, T. 46 N., R. 22 W. The water seems to ooze from the upper part of the Potsdam sandstone, and I obtained up to 2.37 Cl.

In U. S. G. S. water supply paper 114, p. 240, there is an analysis of a well 50 feet in the Potsdam sandstone which is rich in calcium chloride, and I have elsewhere cited calcium chloride analyses from a wide variety of places.*

*Science, 1908, August 2, 1907, p. 127.
American Jour. of Sci., May, 1908.
Geol. Soc. of Am. Bull, Vol. XVII, (1905) p. 691.

For convenience of comparison one recent analysis may be given from the Lower Peninsula—from decidedly younger rocks, however.

Grayling water, Hanson No. 2, 2,800 feet.

Ca	25.044	parts per thousand
Na	52.953	
Cl	147.344	
SO_4	0.137	
Mg	5.361	
Br	1.840	
NH_4	1.033	
K	0.705	
Sum	234.417	
Li. Ba. Sr. Fe.	trace.	
Fe, Cs, Rb	none.	

Calculated as follows:

	parts per thousand
Ca Cl_2	72.627
Na Cl	134.684
NH_4 Cl	3.070
Mg Br_2	2.116
Mg Cl_2	20.128
K_2 SO_4	0.248
K Cl	0.873

Water of crystallization not figured.

Signed, F. B. WILSON.

If the theory of the gradual concentration of salts in the ocean, and especially sodium, is true then the original ocean must have been essentially a weak solution of calcium and other chlorides. It is, however, quite possible that its composition was more or less influenced locally by volcanic emanations, the evidence for which has recently been collected by Lincoln, (1907, p. 258, of Economic Geology).

The present mine waters are often as strong as present ocean water and stronger, and to explain their present concentration, and incidentally throw light on the concentration of the ores also, is our remaining task.

THE PRODUCTION OF NATIVE COPPER IN CHLORIDE SOLUTIONS.

It will be convenient, to save interrupting our discussion of the effects of leaching in modifying the original connate waters, to give here a brief account of some experiments by Dr. G. Fernekes then of the Michigan College of Mines, now of Pittsburg, in which he succeeded in forming native copper from chloride solutions such as the mine waters.

DR. FERNEKES' EXPERIMENTS IN ARTIFICIAL PRODUCTION OF COPPER.

These he has already described.* We may sum up his work, modelled after Stokes,** in a diagram as follows:

Cold water jacket around upper end.	18-inch tube of glass filled with water and sealed.	WATER. Solution of ferrous chloride $FeCl_2$ nearly neutral with sodium carbonate. Few crystals potassium bromide K Br. .2 gram Cuprous chloride $Cu_2\ Cl_2$.
Lower end in sand both at 200° C. to 280° C.		5 grams calcium hydrate CaO_2H_2 or " carbonate $CaCO_3$ or " silicate Ca SiO_3 or prehnite H_2O, 2CaO, $2Al_2O$, $3SiO_2$. or datolite " " , B_2O_3, $2SiO_2$. in fine powder.

Dr. Fernekes then describes the following reactions as taking place.

1. $2\ FeCl_2 + 2\ CuCl_2 = Cu_2Cl_2 + 2\ FeCl_3$.
2. $2\ FeCl_2 + Cu_2Cl_2 = 2\ Cu + 2\ FeCl_3$.
3. $FeCl_3 + 2\ H_2O = Fe\ (OH)_2\ Cl + 2\ HCl$.

—and 10 below.

Now in Stokes', experiments in unequally heated solutions

*Economic Geology, 1907, pp. 580 ff (II. No. 6, Sept. and Oct.)

**Economic Geology, 1906, pp. 644 (I, No. 7, July-August).

like this, sulphate instead of chlorides were used,* so that his equations were:

hotter end.	4. $2\,CuSO_4 + 2\,FeSO_4 \rightleftarrows Cu_3\,SO_4 + Fe_2\,(SO_4)_3$ 5. $Cu_2\,SO_4 \rightleftarrows Cu\,SO_4 + Cu$	cooler end.

hotter end.	6. $Fe_2\,O_3 + 3\,H_2\,SO_4 \rightleftarrows 3\,H_2\,O + Fe_2\,(SO_4)_3$	cooler end.

There is another experiment by Stokes** of interest to us, to-wit:

hotter end.	7. $AuCl_3 + 3\,\underset{}{\overset{\text{ous}}{Cu\,Cl}} \rightleftarrows Au + 3\,\overset{\text{ic}}{CuCl_2}$	cooler end.

We may apply this to the silver which we find most in the upper levels on and later than the copper. While silver chloride is quite insoluble it is soluble enough in these strong chloride solutions for the following reaction slowly to go on.

hotter end.	8. $AgCl + CuCl \rightleftarrows Ag + CuCl_2$ 9. " $+ FeCl_2 \rightleftarrows$ " $+ FeCl_3$	cooler end.

Now as Dr. Fernekes remarked the copper shown in equation 2 did not appear as such, because it would be attacked and redissolved by the HCl set free by reaction 3, until a neutralizing agent was added (eq. 10).

Possibly in nature electric currents or very great length of tube and slow action might help, but there was one obvious reaction, one suggested, too, by the geological conditions[x] we were trying to imitate, to-wit, the neutralization of the acid (H Cl). This was successful, first with calcium hydroxide CaO_2H_2, then $CaCO_3$, then calcium silicate in the form of powdered wollastonite. Copper was deposited within 10 to 15 minutes heating at 200° C. Complete precipitation took a longer time.

*Economic Geology, 1906, p. 644 (Vol. 1, No. 7, July-August.)

**Loc. cit., p. 650.

x In nature the copper is persistently associated with calcium carbonates or silicates and often deposited on corroded surfaces of calcite.

We may add then to the three reactions 1-3 above one more.

$$10. \quad 2\,HCl + Ca\left\{\begin{array}{l} O_2H_2 \\ CO_3 \\ SiO_3 \end{array}\right. \begin{array}{c}\longrightarrow \\ \longleftarrow\end{array} CaCl_2 + 2\left\{\begin{array}{l} H_2O. \\ H_2CO_3. \\ H_2O + SiO_2 \end{array}\right.$$

The above reaction worked freely and rapidly; the copper came down in a fluffy mass.

To obtain it crystallized it seemed natural to use a less soluble neutralizing agent. The following minerals occurred to me from the geological conditions as especially worth trying:

Labradorite $Ab_1\ An_1$ to $Ab_2\ An_3$

(Na_2O, Al_2O_3, 6 SiO_2 + 1 to 1.5 ($2Ca_2O$, $2Al_2O_3$, $4SiO_2$)

Prehnite, H_2O, Al_2O_3, SiO_2 + 2 (CaO, AlO_3, SiO_2)

Laumontite 4 H_2O (Ca, Al_2O_3, 4 SiO_2)

Datolite H_2O, 2 CaO, B_2O_3, $2SiO_2$

Pectolite (Ca, Na_2H_2) SiO_3

Analcite 2 H_2O (Na_2, Ca)O, Al_2O_3, 4 SiO_2

Labradorite and laumontite gave no results. As a matter of fact neither are intimately associated with copper, the labradorite occurring in the fresh unaltered trap, and the laumontite through a secondary zeolite being notoriously a bad sign for copper, though at times pseudomorphs of copper after laumontite do occur.

On the other hand prehnite and datolite both gave positive results, and both frequently occur in nature colored pink with finely divided copper. Capt. J. Vivian has a wonderful collection of flesh colored datolites.

The tubes were heated intermittently, for 10 hours a day, the heat removed in the evening, and again applied the next morning.

After heating the solution and prehnite in this manner five days an explosion took place at about 250° C. A portion of the side of the tube about 5 cm from the bottom was blown off, leaving a cake of mineral underneath which could be seen under a hand lens to be interspersed with shiny particles of crystalline copper. That they were such was proved by tests.

The prehnite had become much darkened, and the particles of the mineral were *stained red with iron oxide.*

Datolite was acted on in a similar manner for six days at the end of which time minute crystals of copper could be detected throughout the mass of the mineral.

It might also be profitable to consider the reactions from the point of view of electro chemistry and ionic dissociation. There is this extra justification for this that experiments by J. M. Longyear and W. W. Stockly have shown measurable differences of electric potential near lodes, and abnormal magnetic variations are not uncommon. In fact from the almost northerly direction of the main chute of the Calumet & Hecla deposit and the great sensitiveness of the copper to electricity it has been suggested that certain electric currents were the determining factors in its deposition.

Schematically we may express the reactions 1 to 3 and 10 in terms of beginning and final products.

11. $2FeCl_3+2CuCl+3CaSiO_3 = 2Cu+Fe_2O_3+3SiO_2 +3CaCl_2$.

That this reaction, which is only a slight modification of that suggested 30 years ago by Pumpelly is really *schematically* the one by which native copper has been formed seems to me almost conclusively proved by the facts:

1. Dr. Fernekes has shown that it actually takes place.
2. The end products are actually the common products of the veins, *and the most abundant constituent of the mine water.*

REACTIONS OF ROCK AND WATER IN THE KEWEENAWAN ORIGIN OF COPPER.

We have then only slight modifications to make to adapt the results of Fernekes to the conditions under which copper occurs in the Keweenawan rocks. This is a great series of ancient lavas separated either by originally porous scoriaceous lava tops or agglomerates or ordinary sediments, the copper occurring in the porous parts, whether amygdaloid, conglomerate or sandstones. It is not certain that these conglomerates were all laid down beneath water. The agglomerates especially may have been laid down beneath the air. But the fact that a conglomerate like the Calumet & Hecla for instance has so little material from the underlying dark trap and so much from felsites which tend to rise above the ocean more than the fluid and less viscous lavas containing more iron would suggest that it was truly marine. Moreover the persistence of these conglomerates as definite horizons for miles points the same way. If they were land deposits there may have been salt lakes in the desert. The fact that the conglomerates are relatively fresher than the amygdaloids may be due simply to the fact that their minerals are on the whole less hydrated, and so have absorbed less water. It seems safe then to assume that some of the conglomerates and some of the amygdaloids were filled with sea water—and it also seems safe to assume that it contained some chlorides, even though not so great a ratio as at present. When the next lava flow would come over it it would be heated. But the amount of heat given off at once would be but a small proportion of that which existed in the lava flow, as lava is a poor conductor and quickly chills at the surface while the interior remains hot. In fact one can walk on the surface while yet the interior is so hot that a walking stick thrust into a crack bursts into flames and the cracks produced by contraction and cooling show a dull red heat.

As I have elsewhere pointed out* in case of lava flows 240 feet thick there is some reason to think that it may be 20 or 30 years before consolidation at the center was finished and that it was nearly 10 times as long before the temperature at the center would drop to say 100° C.**

In the meantime no doubt many other lava flows might have come. Much of the heat of the lava would probably escape upward, and since the specific heat and heat of evaporation of water is very great, and the diffusivity of lava small the water in the underlying beds might or might not be turned to steam.

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*Annual for 1903, p. 248.

**Annual for 1903, p. 248.

We had then at the close of the Lower Keweenawan period a series of many thousand feet of lavas containing here and there streaks of hot water or vapor. These hot waters attacked the lavas and produced the chlorite and zeolites so characteristic of the melaphyres. At first the products of these reactions probably take up more room than the original minerals. Olivine changing to serpentine and magnetite Van Hise* cites as giving an expansion of 30 per cent. And for a change of augite to chlorite, epidote, quartz, and hematite** an expansion of 8.58 per cent is estimated, and most of the changes of the albite and anorthite molecules to minerals of the zeolite group are also changes which produce expansion, though few of them are directly applicable to our problems.

The net result of this first work must also have been that much of the water was absorbed. The deepest and freshest specimens of the traps are hydrated, chloritic, so that what remained was relatively stronger in chlorides. There may also have been some exchange of bases, but the older and deeper seated secondary minerals produced by alteration do not contain sodium and in sections of trap from diamond drill cores the feldspar is often quite fresh. The olivine and then the augite alter first. What sodium was absorbed, if any, most likely came from the glass. The chlorine does not come in any of the secondary minerals formed and so must have accumulated and was[x] either originally present in the water or in the silico-chloride glasses. But calcium carbonate which is insoluble in hot water, is found everywhere and to all depths and chlorite and epidote are equally widespread among secondary minerals. Thus since calcium occurs also in the glasses it would not be safe to venture any guess as to the original amount of lime in the connate water from that in the present mine waters.

With regard to the iron and magnesia dissolved at this stage, the iron may have partly been precipitated and may

*Treatise on Metamorphism, p. 388.

**loc. cit. p. 378.

x Apatite is not recognized in the lavas generally.

have partly remained in solution, mainly as ferrous chloride, since it is ferrous iron that mainly occurs in olivine and augite. But the magnesium according to T. S. Hunt's reactions* would in the presence of calcium carbonate and silicate be thoroughly reprecipitated as hydrous magnesium and ferrous, more or less aluminous silicate. This is so characteristic of melaphyres that green earth (chlorite, diabantite, delessite) has been taken to be an essential constituent. The mine waters, though nearly free from magnesium, may once have contained more in proportion. The ratio of calcium to chlorine in the waters originally may have been more or less than that now, since calcium has been taken up from the augite and thrown down again in epidote, etc., but in the waters of the deep mines the ratio of sodium to chlorine was probably about the same since there are no secondary minerals in which sodium or chlorine have been precipitated and little or no sign of any change by which chlorine could be leached. The present ratio must be greater, if anything. So far as hydration has gone on the concentration is likely to have increased unless affected by circulation of fresh water taken in at the outcrop. Cooling after the first stage of immediate reactions must still have gone on and the water enclosed must have shrunk, and if the rocks had already been so much cemented, that as they cooled they no longer settled so as to squeeze the water out, then—since for water the cubical expansion** and

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*Chemical and geological essays, pp. 138, 122.

In *hot* solution $CaCO_3+MgCl_2 = CaCl_2+MgCO_3$

$CaSiO_3+MgCl_2 = CaCl_2+Mg\ SiO_3$.

**Chem. Cal. 05, p. 85.

Water.

Between 100° & 200° $V_t = V_o$ $(1+.0001082t+.000003$
$t^2 \ldots\ldots\ldots)$

75 100 $(1+.000086\ t+.000003$
$t^2 \ldots\ldots\ldots)$

50 75 $(1+.000059\ t+.000003$
$t^2 \ldots\ldots\ldots)$

28° 50° $(1+.000067t+.0000023$
$t^2 \ldots\ldots\ldots)$

For calcium chloride solution Chem. Kal., '05, p. 83

Between 31° & 54° $V = V_{at\ 29°}\ (1+.000438\ (T-29°)+\ldots$

Glass .000023t .00003 '05, p. 82.

contraction by change of temperature is greater than for rocks* —there would have been a tendency to contract within the rock and draw in fresh water at the outcrop.

Thus a drop in temperature of water from 100° C. 212° F. to 28° C. 82° F. would mean a shrinking of volume of something like 4 per cent. while the contraction of rock for the same change would probably be less than 0.4 per cent.

If now we assume some porous bed of the Lake Superior basin extending from Keweenaw Point to Isle Royale (say the Allouez conglomerate) to have a length of 60 miles across and the water therein to have contracted equally from both sides as it cooled then the early salt waters might have shrunk (.04 x 30 x 6280) about 6300 feet on each side. This would not be equal of course all along the outcrop. The relatively fresh water sucked in by this shrinkage would penetrate farther where topographic conditions and greater porosity favored it and then spread laterally. If any part of the formation was filled when buried not with water but with gas the shrinkage in cooling would be very much greater.[1]

Thus so far as the amygdaloids were buried with the bubbles filled with gas only, and occasional bubbles occur scattered all through quite massive beds of trap, there are tremendous possibilities of absorption. The regularity of this shrinkage and absorption circulation must have been interfered with in various ways. Let us enumerate some of the factors, each of which will be effective only so far as other factors do not interfere.

1. It must have been extensive in the most porous beds.

2. But slide faults, seams or slips on pinches or anything that tends to check the continuity of the porous beds might

*Which is natural as the amount of heat given off in lowering a given volume 1 degree in temperature is about twice as much

1 From 200 degrees to 100 degrees for instance it would be something like $\frac{100 + 273}{200 + 273}$ = .71, something like 30 per cent. of its volume. To this might be added its condensation or absorption.

have checked this circulation as illustrated by the following figures 3 and 4:

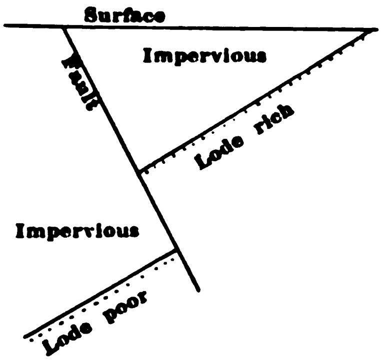


FIGURE 3. Illustrates how a fault may cut off the downward circulation and upper deposition in a bedded lode.

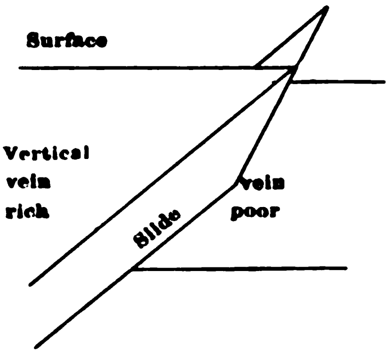


FIGURE 4. Illustrates how a "slide" may cut off the downward circulation in a vertical vein.

3. Topographic conditions such as to produce an upward pressure or circulation will tend to check downward circulation especially in artesian basins or regions that tend to become such. The *circulation may be active for* a limited depth, however.

4. On the other hand beneath higher ground especially if so located as to have water fed in freely at the outcrops there should be an active downward circulation.

There seems to be one factor worthy of special mention. When a bed thickens away from the outcrop, and has but relatively small or thin porous areas at which it reaches the surface the tendency to suction of the upper waters along them will be exceptionally strong if the connections to the surface are kept open.

II. We have then as our second stage the imbibition of the cooler waters from the surface *which may average several thousand feet* and may be more or less than this according to circumstances. This process must have been very slow as we know from hot springs that heat lingers around such enormous masses of volcanic materials for ages.

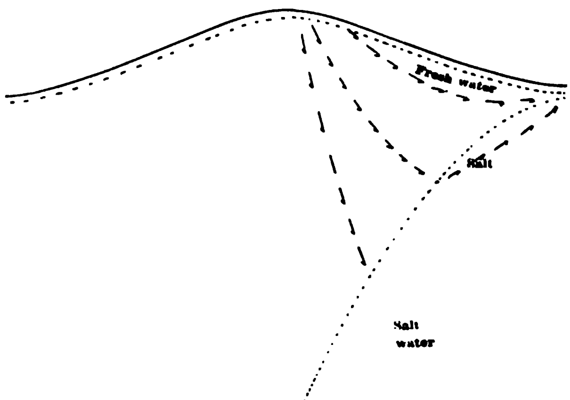


FIGURE 5. Theoretical circulation of water from beneath high ground.

And this brings in a second stage of alteration, an alteration by descending waters, either (a) the original connate chlorine waters migrating nearer the center of the basin, or (b) the same more or less mixed with waters drawn in from the surface. The pressure will increase. The temperature will increase decidedly when they travel in much faster than the formation is cooling and as underground temperatures always increase slightly, will increase anyway somewhat. Moreover we must remember that these upper waters will be pulled in in streaks and sandwiched between quarry moisture of the deeper type in the less porous layers.

Thus along every porous channel on its foot and hanging will be contact zones of the upper water against the lower water, and this is precisely what we really find.

This slow secular sucking of water on a large scale may take the place of Fernekes' repeated action of the same sort described above.

Now what will be the general tendency of reaction of such waters?

1. We may be sure that as they warm up they will tend to dissolve silica and cause it to migrate with them, but as it comes down into waters strong in calcium chloride it may be precipitated (forming prehnite, epidote, etc.) if there is anything else to take care of the lime.

2. Carbon dioxide from the air, or from the rocks will, as in boiler waters, react with calcium chloride and be precipitated as calcite.

3. Sodium carbonates and probably silicates will be be decomposed, if in contact with calcium and iron chlorides, and sodium chloride left in solution.

4. Sulphates will be precipitated in strong salt solution as barite, selenite, etc.

But it is time to leave the purely theoretical and connect with the actual. Real conditions are so complex that pure deduction is unsafe, and it is by no means probable that the relations are everywhere the same.

I shall describe elsewhere somewhat fully the decomposition of a Calumet & Hecla boulder. In this it appears that the abstraction of water glass $(KNa)_2O\ 4\ SiO_3$, the oxidation and addition of iron, the deposition of copper and of magnesia aluminum silicate seem to be the essential factors. One may perhaps add the formation of epidote.

I will simply give a couple of analyses of altered boulders from the Calumet & Hecla conglomerate, (3) by Heath, the other (2) by F. B. Wilson, and also (1) an analysis by F. P. Burrall, of the kind of rock from which they appear to have come judging from the remains of their texture and the porphyritic crystals therein, which are relatively unaltered. At any rate we may be reasonably sure that the original rock contained as much or more silica, and less of iron.

Pumpelly in Vol. I, described the alteration even of quartz porphyries in the same way. It is worth noting that these boulders are less silicious than the traps above and below, so that the alteration is not a mere transfer between adjacent beds.

	1.	2.	3.
Silica	52.83	31.42	36.75
Alumina	16.30	16.83	27.34
Ferric oxide	9.60	15.58	
Ferrous oxide	2.48	12.08	
Magnesia	3.98	3.36	23.24
Lime	2.98	2.84	
Soda	6.54	1.04	
Potash	2.49	1.04	
Water	2.76	14.52	11.07
Manganese	tr.	tr.	
Titanium oxide	n.d		
Difference	0..04	0.34	1.6
Sum	100.00		

In the Keweenawan *igneous* rocks we may make out the two stages of decomposition as follows:

I. 1. Primary reactions, glass decomposes, chloritic filling to cavities, ferric minerals (olivine, etc.) attacked. Chalcedony, agate, quartz, delessite and serpentine, and epidote formed; laumontite, thomsonite and chlorastrolite in amygdules?, iron bearing red calcite, orthoclase? and ankerite?. Some of these reactions may not be all primary.

II. Secondary reactions.

2. Prehnite, other kinds of chlorite, also epidote and quartz formed lime bearing minerals dominant.

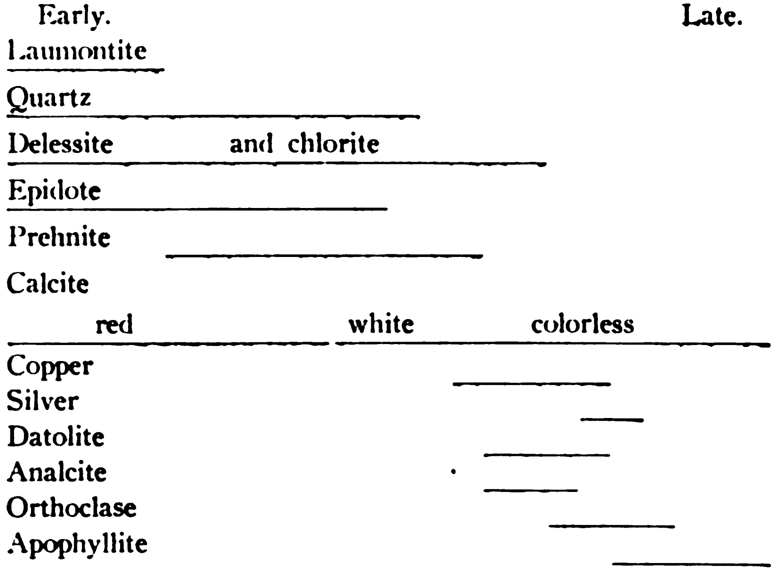
3. Iceland spar (calcite) and copper formed.

4. Datolite, orthoclase, natrolite, apophyllite, analcite, and the sodium bearing minerals, flucan.

In the four groups above it must not be understood that the order is absolute but that on the whole the copper is most intimately associated with calcite, but at times occur sprinkled through the prehnite and epidote as the contemporary.

It is, however, true that the minerals of the last group are rarely if ever formed before those of the earlier ones. It is understood of course that primary orthoclase of the original felsites may be and often is replaced by the others, and calcite occurs of all ages. An older calcite is often bright red.

These studies are adapted from Pumpelly's original studies of the order of crystallization, Volume I, part 2, p. 32, of these reports, with additions.



Coming back to our idea of the sucking in of surface waters and picking out from the numerous ions existing in the waters only those most necessary to understand the reactions* we have:

1. $Na_2CO_3 + Ca\ Cl_2 = 2\ Na\ Cl + CaCO_3$

$CO_2 + O + Ca\ Cl_2 = 2\ Cl + Ca\ CO_3$

Good sized salt crystals have been found in the upper levels of the Calumet & Hecla and the middle belt of waters rich in

*But not forgetting that the presence of other ions may be necessary in order that these reactions may go on.

sodium chloride is thus easily accounted for. Bi-carbonates of lime and magnesia might go farther down without being precipitated though in stronger solutions of $CaCl_2$ they are less and less soluble.

2. $NaCl + Al\ Cl_3 + 2\ SiO_2 + Aq = Na\ Al\ Si_2O_8 + Aq + 4\ Cl$

This is merely a theoretical reaction that may go on momentarily in the zones where the analcite, orthoclase and apophyllite are formed. By slight changes the same type of reaction may be made to apply to orthoclase and datolite. It is noteworthy that this leaves Cl in the downward working water.

In the presence of salt (sodium chloride) iron tends strongly to rust, and salt and red rocks are everywhere associated. So with a reaction that produces sodium chloride it is natural to add one that produces ferric oxide if there is any iron chloride in the solution.

3. $3\ H_2O + 2\ FeCl_3 = Fe_2O_3 + 3\ H\ Cl$

Put the HCl of this reaction in the place of NaCl of 2 and combine 2 and 3 and we have a reaction that will produce the red flucan clays. It is noteworthy that the secondary orthoclase is generally reddish and brick red orthoclase and analcites are not unknown.

Capt. J. Pollard has a pebble from the Calumet & Hecla dissolved out so as to leave a vug lined with beautifully crystallized orthoclase and hematite.

This reaction very probably does not take place except in the presence of other ions, but it went on as Fernekes' test with prehnite showed to some extent under those conditions, as red oxides were formed.

But reactions 1, 2 or 3, or in fact *any reactions* in which chlorine is crowded out from union with chlorides *must* give us chlorine ions to migrate. Then this chlorine in breaking up *any* silicates with the formation of silica will release oxygen, and may form ferrous chloride which in the presence of an excess of oxygen may make ferric iron, or if there is no such excess, may be oxidized as in Fernekes' test, while the copper is thrown down in metallic shape.

We also *know* that the substances mentioned in the equations exist in some of the upper waters, and that the minerals marked as precipitated are in fact precipitated in the upper levels and among the late constituents.

These reactions 1 to 3 also tend to produce an excess of chlorine* and in the presence of this chlorine copper cannot be deposited, nay rather copper already deposited would be dissolved and moved on down to where the chlorine could be neutralized as in Fernekes' experiments. But silver would be much less readily dissolved than copper and so would occur higher up, as indeed it does, and when moved on would lag behind the copper and be deposited on it. This is also true. The Calumet & Hecla was distinctly richer in silver at the south upper end, and speaking generally the upper levels are said to be rich in silver. Thus in the process of down migration from the surface, waters which have undergone reactions 1, 2 and 3, may give us:

4. $Cu + Cl_2 = CuCl_2$

and with more difficulty if already well saturated with $CuCl_2$, and $Na\ Cl$.

5. $Ag + Cl_2 = Ag\ Cl_2$.

At the same time the chlorine set free in equations, 2 and 3 will attack calcium carbonate if originally present and if by any displacement or change in circulation the calcium carbonate formed by equation (1) should get back into the way.

The reactions might be written in two installments.

6. $2\ CaCO_3 + 4\ Cl = Ca\ O_2\ Cl_2 + CO_2 + CaCl_2$.

7. $CaCO_3 + CO_2 + H_2O = (H_2\ CO_3 + CaCO_2)$.

8. $3\ CaO_2\ Cl_2 + 4\ Fe\ Cl_2 = 2\ Fe_2O_3 + 4\ Cl_2 + 3\ CaCl_2$

Now since it would be strange if there were not more or less carbon dioxide in the original lavas and buried waters and

*I do not mean to say that there is an excess of chlorine in the waters. There is not. Nor does the chlorine exist free except in ionic electrolytic dissociation so that it can migrate.

more or less calcite also in the sediments, we may expect to find, as we do, native copper and calcite which may have been formed earlier and dissolved and driven ahead of the chlorine.

While therefore generally speaking the copper is earlier than the alkaline zeolites. I have seen one specimen, said to come from the Osceola amygdaloid in the Centennial mine, which seemed to have copper moulded around rectangular needles of natrolite.

Such reactions are entirely explicable on the hypothesis of migration and removal downwards.

They also give a chance for oxygenation *whenever chlorides are formed from silicates.*

These reactions 6 to 8 are only ideal ones to show how the chlorine may be pushed on as the iron oxidizes.

If we attack the bi-carbonate product of reaction 7 we have:

9. $(H_2CO_3\ CaCO_3) + 3\ FeCl_2 + 2\ CuCl_2O_2 = FeCO_3 + CaCO_3 + Fe_2O_3 + 2\ CaCl_2 + H_2O + 6\ Cl$

But in the presence of a large amount of chlorides and very little CO_2 according to the principle of mass action the CO_2 is more likely to go into solution.

10. $(H_2CO_3.\ CaCO_3) = CaCO_3 + CO_2 + H_2O.$

Such reactions may suggest the method of formation of the red calcite and red ankerite, which are as we know relatively early products of alteration, and also show how acid ions are continually shoved ahead to find new affinities.

The copper is readily dissolved by the chlorine and in any such reaction will be dissolved to be precipitated, as in Fernekes' experiments, in presence of a stronger neutralizing agent.

In these experiments, sodium carbonates, calcium carbonate $CaCO_3$ and silicate $CaSi\ O_3$, wollastonite, prehnite $H_2Ca_2\ Al_2\ Si_3O_{12}$ and datolite $H\ Ca\ B\ SiO_5$ were used. Judging from what we see in nature, and the minerals copper replaces we may be sure that chlorite and epidote very often, even laumontite and quartz sometimes, should be added to the list, and in fact *almost any rock*, for great masses of trap and solid pebbles of conglomerate may be changed to copper. The reactions are ones of equilibrium with a large number of ions. Take the simplest:

11. $CaCO_3 + FeCl_3 + 2\ CuCl + H_2O.$?

The products are:

in solution + ions Ca (comes in), Fe, Cu (goes out), H; – ions CO_3, Cl? OH , FeO_3. Besides this there are at various temperatures and concentrations, various amounts of undissociated salts, and possibilities of ions like OCl and Fe O_3. The general effect of dissolving $CaCO_3$ it to add a strong + ion and a weak negative ion. One way to keep balance in the solution is to eliminate some other + ions, which may be and is accomplished by precipitating the copper, and also by converting the + ions Fe into negative FeO_3. If it were not for the possibility of using the O of the–ions CO_3 and CH in converting the + ions Fe into a – ion FeO_3 which is the kind of change needed to restore equilibrium, the copper ion might take CO_3 or the O of the OH with it. This is what presumably happened in the Allouez conglomerate at the Allouez mine where cores of native copper are surrounded with oxides and carbonates of copper and chrysocolla for quite a depth. This is exceptional, however. The zone of carbonates is extremely shallow generally and native copper often occurs "at the grass roots".

The same principles apply if for CO_3 we write SiO_3*, and so with the attack on prehnite.

12. $H_2Ca_2\ Si_3O_{12} + CaCl_2 + FeCl_2 + CuCl + H_2$

will result in a solution of

+ ions Ca, Fe Cu H, (AlO_3?) (Si?)

– ions SiO_3 (FeO_3?) (AlO_3?) Cl OH

*Though there is the possibilty of the formation of compounds like $SiCl_4$ and $SiFe_4$ which account for the solution of pure quartz, though, rarely, with difficulty, and as a last resort. There must be a relatively large amount of cuprous chloride and little silica in solution in order to favor this reaction.

As the Ca comes in the Cu drops out. It is not certain just why the laumontite does not precipitate the copper so readily as the prehnite, though the fact is clear both naturally and artificially. That it has less of the stronger bases + ions like Ca and H and more of the -- ions (even though weak) like SiO_3 and AlO_3 is significant. The formulae are:

Prehnite $H_2Ca_2\ Al_2\ Si_3\ O_{12}$

Laumontite $Ca\ Al_2\ Si_4\ O_{12} + 4\ Aq$

The solutions obtained in dissolving laumontite would be much richer in alumina and silica and thus in oxygen in proportion to lime. This might tend to favor the direct oxidation of the ion. Red colors are associated with laumontite.

With the very common feldspar (Ab_2An_3)i.or labradorite the change to prehnite and epidote is very simply written.

$$Ab_2An_3 = 2\ (Na_2O\ Al_2O_3\ Si_6O_{14}) + 3\ (Ca_2Al_4\ \ Si_4\ O_{16} =$$
$$2\ Na_2O\ 6CaO\ 8\ Al_2O_3\ \ 24\ SiO_2$$

add 8 H_2O + 10 Ca and subtract 2 Na_2 and we have prehnite: 8 H_2O 16 CaO 8 Al_2O_3 24 SiO_2. So that this would mean simply the replacement of Ca by Na in the mine water, and its concentration.

The formation of the *epidote* is of considerable importance. Its formula is:

Epidote $H\ Ca_2\ (Al\ Fe_{1\ 6}\ \text{to}\ _{2\cdot 3})\ Si_3O_{12}$ 2

Prehnite $H_2Ca_2\ \ Al_2\ \ Si_3O_{12}$

As compared with prehnite the difference is that there is less hydrogen, considerable ferric iron (about 10%). There is no reason why it might not act as a precipitant of the copper just as we know prehnite does, but less readily as there are fewer + ions.

There are two kinds of epidote, -- a pale colored zoistic kind which is formed in the decomposition of the feldspar and a deeper colored epidote* which is the commoner variety and no doubt is richer in iron. The epidote is very commonly as-

*Thallite or pistazite, yellow in thin section, deep yellow green. Volume VI, Part 1, p. 166.

sociated with chlorite in sharp crystals. The chlorite takes in magnesia and ferrous iron, but not willingly or to any great extent lime and ferric iron. Therefore in the hydrous decomposition of the augite, the lime, alumina and ferric iron of the same are precipitated in epidote as the solution gets over loaded with lime. This early epidote is formed before the copper and is very wide spread where there is no copper, and is almost as wide spread if not quite as abundant as the chlorite.

Epidote also, however, occurs replacing the whole mass of the rock. In this case the feldspar and glass of the amygdaloid are also decomposed. It we compare the formula of epidote with that of feldspar we see at once that there will be silica left over* in its formation. And if we take the trap as being roughly** CaO, MgO (Na_2O FeO) $(FeAl)_2$ O_3 $4SiO_2$ and suppose it decomposed into chlorite = $(2FeSiO_3)$, Al_2O_3, 3 SiO_2, 3 Mg $(OH)_2$, Fe $(OH)_2$ and epidote = $(AlFe)_2O_3$ 3 SiO_2, CaO, CaOH we see clearly that there must also be as in the Calumet & Hecla pebbles. Silica (quartz) SiO_2 and soda Na_2O to be accounted for. We do as a matter of fact find quartz commonly associated with epidote and chlorite but often later, the sodium silicate being quite soluble, but precipitated by calcium chloride, giving calcium silicate for epidote.

In the lower part of the lava flows, the hanging of the lodes, there is an accumulation of the lime and iron, while at the top, which is the foot of the amygdaloid lodes there is more sodium (feldspar). Nevertheless generally speaking the hanging is chloritic, the foot and the amygdaloid itself more epidotic.

The lime and silica are always abundantly present and the more important conditioning factors seem to be the presence

* H Ca_2 $(Al\ Fe_{1\ 3})2$ Si_3O_{12} epidote
Ca_2 $(Al_4$ Si_4O_{16}
Na_2 Al_2 Si_6O_{16}

**Proc. L. S. M. I., XII, p. 85.

of alumina, and the accumulation of oxygen to oxidize the iron.

This might very well go hand in hand with the formation of copper, and indeed it does, if only the physical conditions were such (as in Fernekes' tubes) that the oxygen derived from the decomposition of silicates by chlorides was preferably employed in building epidote. On the whole, however, epidote is vastly more widespread than copper, that is in the attack of silicates the oxygen was in most cases provided for change from the ferrous iron of traps and chlorites to the ferric iron of the red amygdaloids and epidote without reducing the copper.

Of especial importance is the role of the chlorite family for they are so widespread and often replaced by copper. They have had a great many formulae assigned* but the essential thing to remember is that they are a hydrous alumo magnesian silicate with the magnesia always largely replaced by ferrous ferrous.

The chlorite naturally forms first in the hydration of ferrous minerals like olivine and augite. But that is only the beginning of the story. Chlorite is attacked by chlorine and H Cl, and as soon as corrosive chloride solutions reach a delessite, that bears ferrous iron, they will readily attack it. It is not uncommon to find amygdules that look like solid copper but are a fraud. They were coated with delessite and then this has been attacked and replaced by a thin film of copper that coats around the outside of the amygdule as though it were the first formed.

So the early chlorite is very apt to be attacked by the migrating mine waters. But the mineral brought into solution

*Besides the chlorites proper, mainly a combination of a serpentine molecule $H_4 Mg_3 Si_2O_9$ with $H_4Mg_2 Al_2 SiO_9$ we have delessite $H_4 (MgFe)_2 Al_2 Si_2O_{11}$ and diabantite $(H_2O)_{57} (MgO)_{53} (FeO)_{38} (Al_2O_3)_{11} (SiO_2)_{51}$. A common type of analysis would be SiO_2 30, Al_2O_3 13, FeO 25, MgO 20, H_2O 10.

cannot remain in solution. Hunt has remarked that magnesium chloride is precipitated by calcium silicate and carbonate quite completely, and there is very little magnesium chloride in the mine water—barely a trace. It seems, therefore, that the magnesium chloride is thrown out again as chlorite as fast as it is brought into solution, but with this difference, that if there is copper chloride present a proportionate amount of ferrous iron remains permanently in the form of ferric iron, either as, hematite or epidote, while the copper takes the place of that much of the chlorite.

This may be written (remembering that all the magnesian part of the chlorite and most of ferrous remains chlorite), for the fraction of the chlorite that reduces the copper, and the fraction of the epidote which has ferric iron.

$$3\ H_4Fe_3\ Al_2SiO_{11} + CaCl_2 + 5\ CaCl_2 = H_2\ Ca_4\ Fe_6\ Si_6\ O_{26} + 6\ AlCl_3 + 5\ Cu + 5\ H_2O.$$

The aluminum chloride shown in this transformation from chlorite to epidote has probably been used in making more chlorite out of relatively not aluminous minerals like augite and olivine.

The latter seems to be the reaction at lower levels, and may be the source of much of the chlorite on veins, joints and fissures.

We have now it seems to me reactions enough to account in principle for all the phenomena of the copper lodes, without supposing anything unlikely in the course of circulation, the elements previously dissolved, the character of the country rocks or the temperatures, while there is yet very much to be learned with regard to the relative solubility of the ions concerned.

Pumpelly's theories seem to be altogether confirmed except that chlorine rather than sulphuric anhydride was the acid radical.

It is perfectly possible to conceive a formation of copper with no surface waters concerned.

Take a glass with an ophite composition in the presence of water, say

$$CaO,\ MgO,\ (aNa_2O\ bFeO\ cCuO)\ (dAl_2O_3\ eFe_2O_3)\ \ 4\ SiO_2$$

$$a + b + c = 1$$

$$d + e \quad = 1$$

add enough water $\times\left(= \frac{7}{6} + \frac{8}{6} d\right)\ H_2O =$

We have:

$d(H_4Mg\ (Al_2O_3)\ SiO_4)$ (chlorite molecule).

$\frac{1}{3}\frac{(1 - d}{}\ \ (H_4\ Mg_3\ \ Si_2O_9)$ (serpentine molecule).

$\frac{1}{2}(H_2\ Ca_2\ (2e + b\ \ Fe_2O_3)\ \ Si_3O_{12})$ (epidote).

$+\ a\ (Na_2O,\ \ 4\ SiO_2)$ (water glass in solution.)

$+\ ?\ \ (d\ \ 2/3\ \ 2d/3\ \ 3/2\ \ 4a\ )\ \ SiO_2$ (quartz).

$+$ $c\ Cu$ copper.

if $c = \frac{1}{2}b$ and if not, we can simply leave a certain amount of the iron in the chlorite molecule.

The accumulation of sodium silicate in solution as in the change of the Calumet & Hecla pebbles is noteworthy. This will in turn react with calcium or ferrous chlorides, leaving sodium chloride in solution. But to have valuable accumulation of copper there must be not merely the decomposition of the rock and the concentration of the copper near by but a considerable migration, since the rocks on the average run only something like 0.02% of copper. Unless, therefore, there was a migration of the water it could only take a little from the rocks or add a little to them until equilibrium was established.

But it is probably true that in nature the chlorine waters act not merely locally but on a large scale in their slow migration tending to sort and collect the different ingredients, the arrangement being similar laterally and vertically, but differing somewhat according to the temperature and pressure in exact composition. For instance epidote might be formed in depth where in the presence of a water of corresponding concentration near the surface the oxidation of the iron oxide would lead directly to hematite and red clays. Nearer the surface too there might be more CO_2 and the lime go into carbonates.

Thus the surface lateral alteration from the main channel of porosity and the downward succession are *not* exactly the same and the zones of formation of the minerals do not run exactly parallel everywhere. Cross fissures, sliding and slipping, the varying chemical character of the different flows, the varying amount of water originally in the beds,—all these are factors of which account may be taken in explaining the general trend of events, which may be summarized in the following diagram.

The main purpose of this rather long discussion is however to show that in the secondary changes of the mine waters and in all the reactions leading to the deposition of copper there is an accumulation of *sodium* in the mine waters, the same accumulation which we find actually has taken place in the upper part of the lower waters.

After the copper is formed the sodium accumulates to such an extent that sodium minerals are precipitated.

FOR CONVENIENCE THE DIP IS TAKEN AS VERTICAL.

Generally feldspathic footwall.	Surface previous lode	Generally augitic hanging wall
Ferric zone. Surface decomposed zonefull of fractures and of water coming from the surface only a few feet deep. Red colors—amygdaloids, hematite formed. Soda zeolites may be formed.	Water largely circulating fresh Na : Cl more than .65 chlorine less than 200. Carbon dioxide from surface form carbonate. Chlorine increases by diffusion, but sodium both by solution and diffusion of feldspars. Copper dissolved and carried down by the chlorine released in the formation of hematite and soda zeolites.	**Much like the foot but more chlorite and augite less epidote and feldspar.**
Ferrous zone. Copper is formed or accumulated in a zone laterally and downward where the tendency of the copper to be attacked is neutralized by the supply of decomposible silicates, chlorite, prehnite, etc. ferric iron present built into epidote.	Water, almost stagnant, gets stronger. The proportion of sodium falls as with depth it approaches the original water down to Na : Cl (.07).	
Early alterations, water absorbed, feldspar and augite and olivine changing into epidote, chlorite, and serpentine. Glass decomposed, partial amygdaloid filling, original CO_2 gives carbonate,	Chlorine soon measured in per cents, maximum 17.6 grams per liter. Generally augite Hanging wall.	

IRON COUNTRY WATERS.

The iron country waters are on the whole fresher. I think though they are so much less deep that it is hard to make comparisons. This may be due to more profound downward circulation, but I think also to the fact that the associated rocks are not so subject to hydration as the Keweenawan traps. Yet they are more or less hydrated, the dikes on the Gogebic changed to Kavlin and the Ishpeming diorites or amphibolites to "paint rock" and chlorite schists.

Years ago I suggested* the derivation of iron ores directly from these altered igneous rocks, very much as the iron has accumulated in the Calumet conglomerate pebbles whose analyses were above cited. But while it is generally accepted, for instance by Leith in the current volume of Economic Geology, that the iron ores have been derived from the greenstones, it is altogether likely as he holds that the larger deposits have been formed by the accumulation of these leachings in the water, whence they precipitated, most likely, according to the analogies of present happenings with the assistance of some lowly forms of living matter. But in some cases the iron ore directly leached from the greenstone formation (Kewetin) may have replaced some limestone or chert.

Finally these beds have in some cases been leached again, and still farther enriched by waters circulating from the present surface. How important this enrichment from the present surface is remains to be seen, so far as one can judge it is the dominant factor on the Mesabi, but it may not be so everywhere. If we should find iron ore deposits continuing in unimpaired richness to a depth where the strongly saline character of the mine water was such as to show that no great circulation of fresh water from the surface was now taking place we should have to infer that enrichment relative to the present surface was relatively unimportant, or that that there had been a diffusion of these salt waters into the ore bodies laterally or

*Annual Report State Geologist of Michigan for 1892, p. 181.

upward since they were formed, or that we are entirely mistaken in our idea that chlorine is not readily leached from the rocks.

The pebbles of iron ore found in the Upper Keweenawan conglomerates, and in Huronian conglomerates as well, show that part of the iron ore formation took place at a very early date.

THE HYDRO-ELECTRIC PLANT OF PENN IRON MINING CO., AT VULCAN, MICHIGAN.

BY THOMAS W. ORBISON, APPLETON, WIS., AND FRANK H. ARMSTRONG, VULCAN, MICH.

In 1877, the Republic Iron Co., installed a hydro-pneumatic plant on the Michigamme river, with transmission of about one mile, to furnish power for the operation of the Republic mine. Five years later the water power at the upper Quinnesec Falls on the Menominee river was improved with the installation of an air compressor plant, the transmission being about 3½ miles to the Chapin, Ludington and Hamilton mines at Iron Mountain, Mich.

These plants have been in successful operation all this time. Up to and until about one year ago they were the only water powers in all the Lake Superior district being utilized for mining purposes, notwithstanding the abundant tributary water power on the one hand, and the enormous consumption of coal required for power, on the other.

Though there are many reasons for the slow development of these water powers, the chief one has been the lack of a satisfactory medium of transmission, applicable to the successful operation of mining machinery, and economical in cost. Compressed air, as a medium of transmission meets the first of these requirements and is indispensible in mining operations. The cost, however, is great under favorable conditions, and increases rapidly with the length of the transmission.

The mine operator, therefore, has been watching with great interest the wonderful progress made in the last few

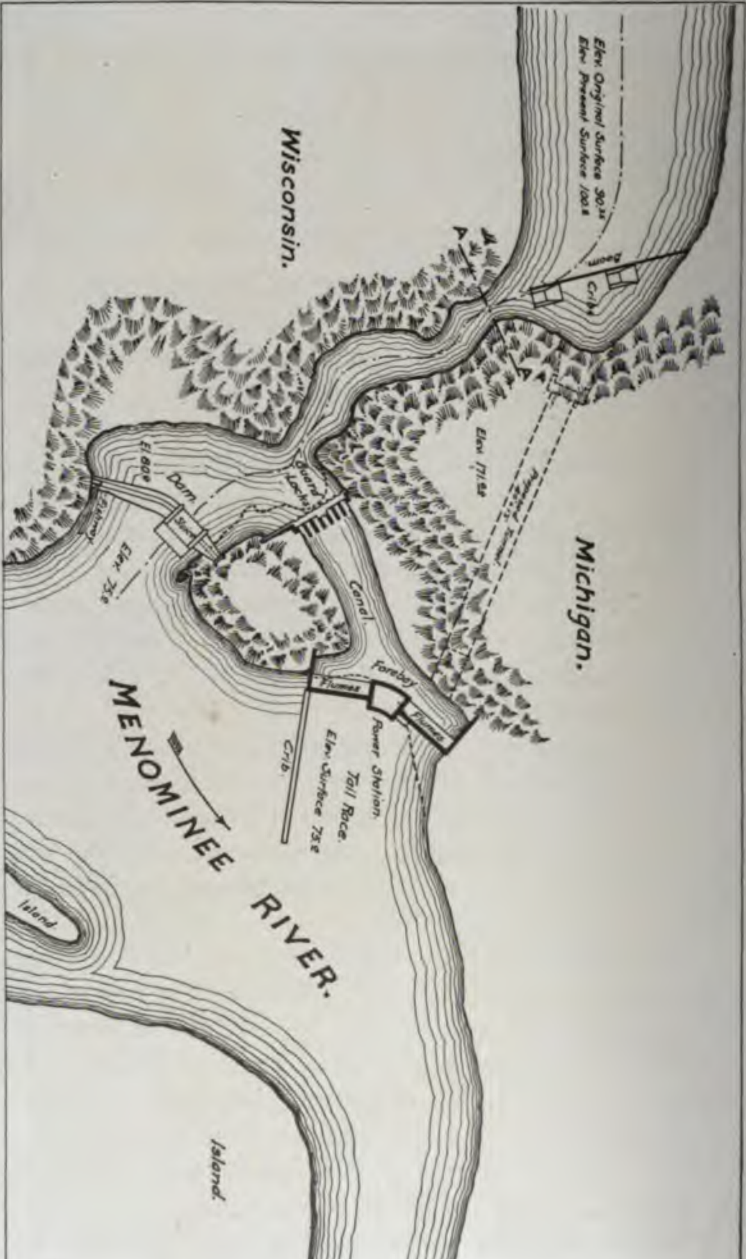

Wisconsin.
Michigan.
MENOMINEE RIVER.
Dam.
Canal.
Forebay
Flumes
Flumes
Power Station.
Tail Race.
Crib.
Crib.
Island.
Island.
Elev. 75.8

FIG. I

FIG. 2

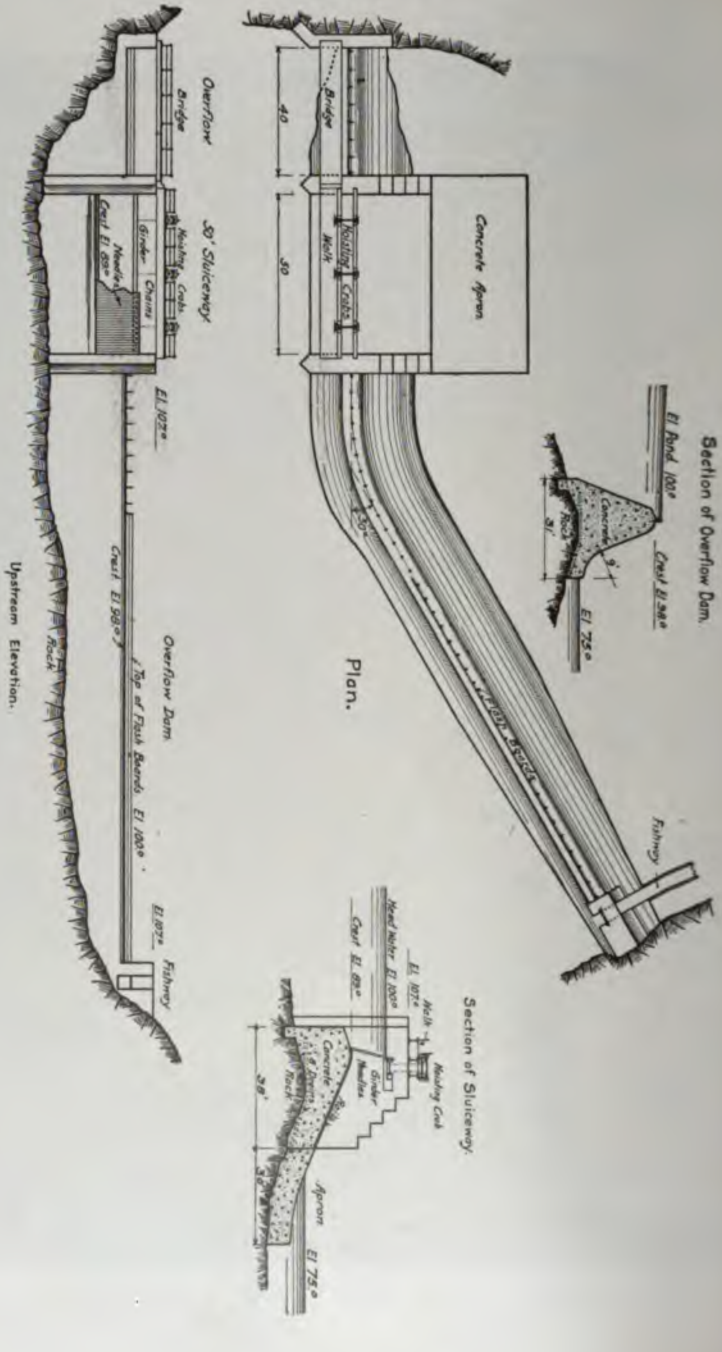

Section of Overflow Dam.
El Pond 100°
Crest El 98°
Concrete
Rock
El 75°
Concrete Apron
Bridge
Walk
Hoisting Crabs
40
30
Plan.
Fishway
Section of Sluiceway.
Head Water El 100°
El 107°
Crest El 85°
Walk
Hoisting Crab
Girder
Needles
Concrete
Rock
Apron
El 75°
Overflow
Bridge
30' Sluiceway
Hoisting Crabs
Girder
Chains
Needles
Crest El 85°
El 107°
Crest El 98°
Overflow Dam.
Top of Flash Boards El 100°
El 107°
Fishway
Rock
Upstream Elevation.

FIG. 3

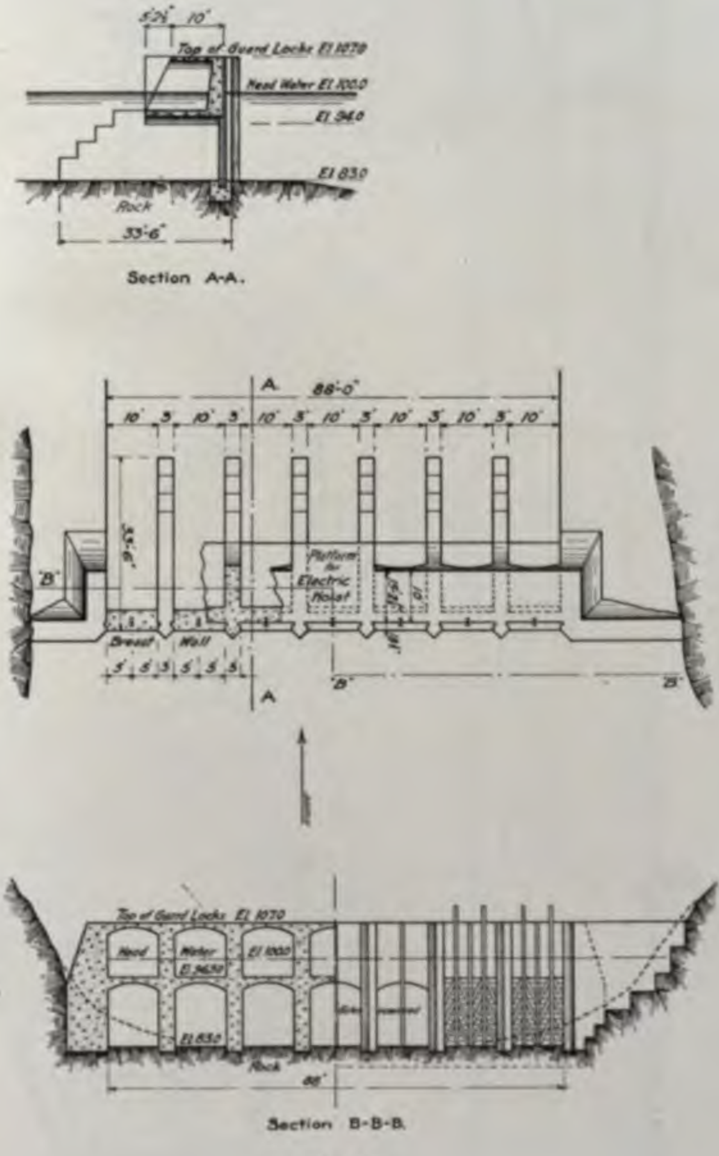
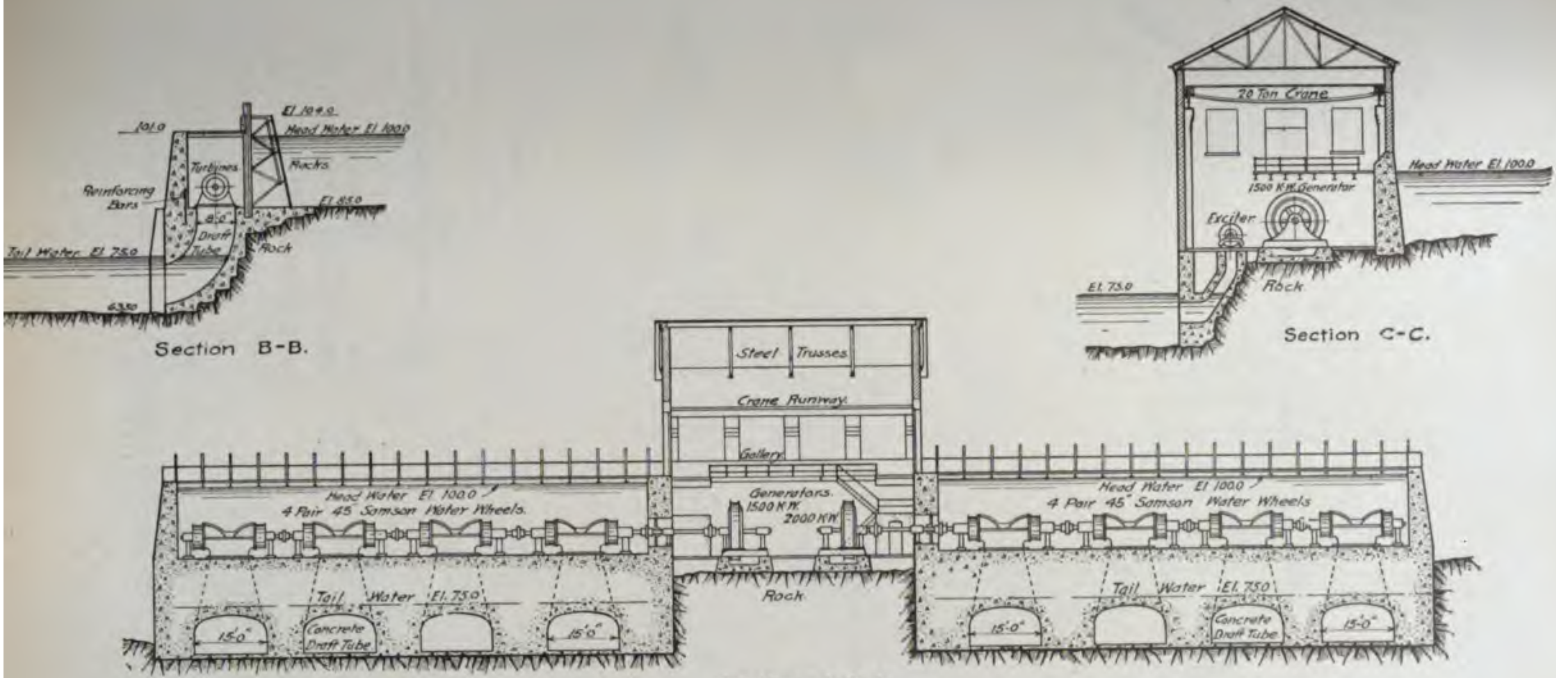
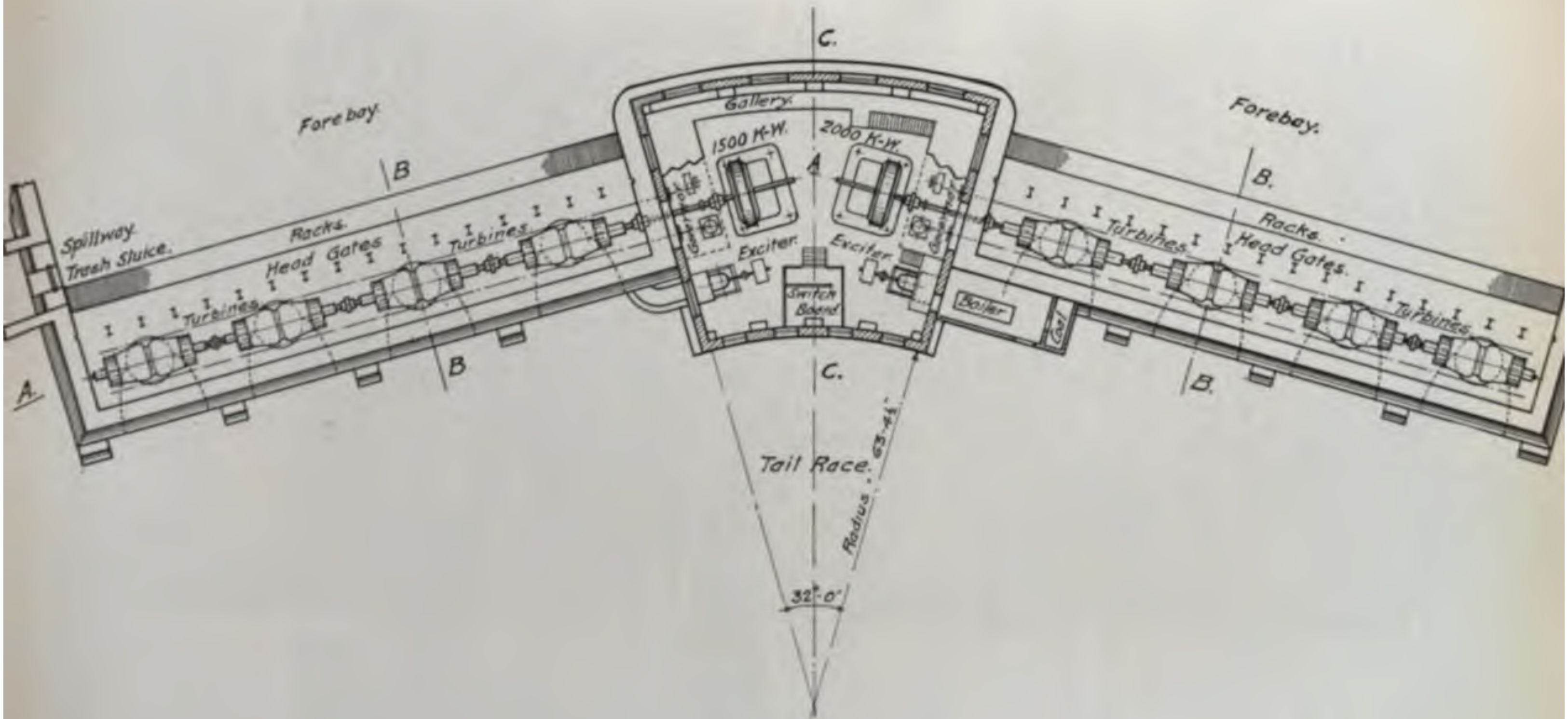

Top of Guard Locks El 107.0
Head Water El 100.0
El 94.0
El 83.0
Rock
33'-6"
Section A-A.
88'-0"
Platform for Electric Hoist
Breast Wall
Top of Guard Locks El 107.0
Head Water El 100.0
El 83.0
Rock
88'
Section B-B-B.

FIG. 4



Section A-A-A.

FIG. 5



Fore bay.
Forebay.
Spillway.
Trash Sluice.
Racks.
Head Gates
Turbines.
Gallery.
1500 K-W.
2000 K-W.
Exciter.
Switch Board
Boiler
Coal
Tail Race.
Radius 63'-4½"
32°-0'
A.
B
C.

FIG. 5

years in electrical transmission, and the application of this power to his requirements.

In the fall of 1904 the Penn Iron Mining Co. Vulcan, Mich., began an investigation of their water power at Sturgeon Falls on the Menominee river, Mich., to ascertain the amount of power available, the possible plans for its development and transmission by means of compressed air or electricity, and the application of the power to the operation of the mines, at Vulcan, about three miles from the falls.

AMOUNT OF POWER.

The Menominee river has a drainage area at Sturgeon

FIG. 6

Falls of 2929 square miles. The average annual rainfall is 31.15 inches. The run-off, in ordinary low water, is estimated at 1266 second feet. The available head is 25 feet. There-

FIG. 7

fore, at ordinary stages of water, there is 3600 theoretical horsepower, or 2880 horsepower delivered by the turbines. For a large portion of the year the flow is very much greater, and this fact was taken into consideration when the capacity of the machinery installed was decided upon.

PLANS OF DEVELOPMENT.

Figure 1 shows the river at the falls, and two general plans for the improvement. One is for a dam at AA, with a tunnel through the bluff to the forebay at the power house; the other

FIG. 8

is for a dam located further down stream on the top of the last pitch in the rapids, with a canal through a depression, leading the water to the forebay. The latter plan was adopted, because the estimates showed that its cost would be less, even with the longer and higher dam, and the longer dam would provide more spillway for the disposal of flood water, and facilitate the handling of the saw-logs that are floated down the river.

THE MEDIUM OF TRANSMISSION.

In discussing whether to transmit by compressed air or electricity, four things were considered: First cost, efficiency, net saving, and reliability.

First Cost: Carefully prepared estimates showed that the installation by compressed air would cost 14 per cent more than the electrical installation, including all changes for the mining machinery.

In a new installation, requiring the purchase of all the ma-

FIG. 9

chinery at the mine, the percentage in favor of electricity would be very much greater.

Efficiency: The divison of power used at the Vulcan mines, at the time of the investigation was,

For pumping water, 74.4 per cent.
For compressed air, 12.2 per cent.
For hoist, etc., 13.4 per cent.

Three manufacturers of electrically driven turbine pumps made propositions guaranteeing an efficiency of over 60 per cent., and in our investigations, we assumed that efficiency.

It was estimated that it would require 54 per cent. more power to do the required work with compressed air, than if electricity was used.

Net Saving: The saving in fuel, labor and maintenance was estimated to be sufficient to warrant the expenditure. The estimate showed that there was very little difference in the

FIG. 10

saving in the two methods of transmission, except in the efficiency as stated above.

Reliability: The experience of the last few years has proven that in its manufacture by water power, electricity is even more reliable than compressed air. In the application to the operation of mining machinery, compressed air had been proven to be very reliable, while on the other hand electricity had been almost untried.

At East Vulcan there was 700 gallons of water per minute to be raised 1000 feet. At West Vulcan 1800 gallons per minute to be raised 1200 feet. The inquiry failed to locate an instance where such volumes of water had been taken care of with turbine pumps under like heads, or an installation of sufficient size to establish a precedent. Although confident that the turbine pumps would eventually do the work, the question was, would it pay to undertake the experimental stage that seemed unavoidable.

There was also some apprehension as to the reliability of electricity applied to the operation of hoisting engines.

The facts as above stated, were submitted to the engineers

FIG 11·

of the company in the East, in July, 1905. At this conference, for the reasons above cited, and for the reason that at times of low water the mines would require the full power with a most efficient installation and transmission, it was decided unanimously to recommend the improvement of the water power electrically, and that it be applied to all departments of the work, including turbine pumps and geared hoists.

CONSTRUCTION.

In August the work was authorized and operations were commenced at once. Little was done, however, until September, except in the improvement of the road leading to the falls, and the building of camps for the laborers.

Figure 2 is a photograph of the river on September 28, when the first cribs for the coffer-dam were being located. This shows in the immediate foreground the location of the dam, in the upper right-hand corner the concrete mixing plant,

FIG. 12

and in the center of the picture, the entrance to the depression through which the canal was excavated.

Figure 1, already referred to, shows in heavy lines the general lay-out of the dam, guard locks, canal, forebay and power house.

Figure 3 is a plan of the dam with elevation and sections; it also shows the log sluice and fishway.

Figure 4 is a detailed plan of the guard lock, by means of which the amount of water let into the forebay is regulated or entirely cut off.

Figure 5 shows the plan and sections of the power house and flumes, and the location of the machinery installed.

Figure 6 is a picture taken December 4, 1905, showing the derrick by which the rock for the concrete work was raised from the cut for the canal to the crusher; the concrete mixer; the boiler plant; the cement house, and in the foreground the

FIG. 13

track for the cars, by which the concrete was delivered to the dam.

Figures 7 and 8 are photographs of the dam taken January 6, 1906, and after it was entirely completed.

Figure 9 shows the river above the dam, and a portion of the guard lock at the entrance to the canal.

Figures 10, 11 and 12 are photographs of the power house; the first showing the forms soon after the concrete work was


Norway Mine
Aragon Mine
Currie Mine
West Vulcan Mine
Brier Hill
Transformer House
C. & N.-W. Ry.
Vulcan
East Vulcan Mine
Transformer House
Norway.
Lake Hanbury
Wis. & Mich. Ry.
Transmission Line.
MICHIGAN.
Menominee River
Sturgeon River
WISCONSIN.
Power Station.

FIG. 14

started; the second, when the flumes were nearly completed; and the third after the work was finished. It will be noticed that there is an angle in the power house. The reason for this is that the power house and flumes are founded on solid rock, and this line was adopted to conform with the natural contour, and thereby save a large quantity of excavation.

Figure 13 is an interior taken recently.

The dam was completed in the latter part of January, 1906,

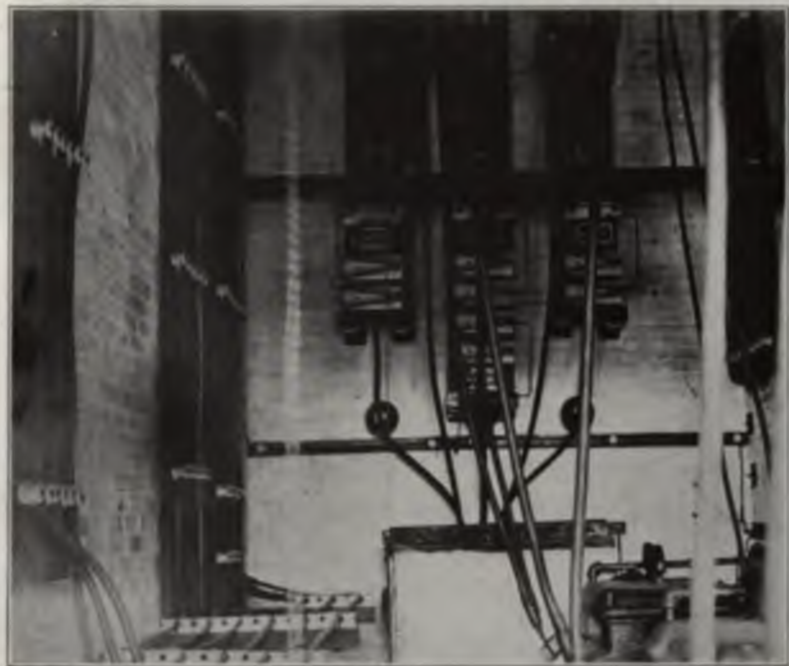


FIG. 15

the power house late in the fall of the same year, and the machinery for the first unit was installed in the winter of 1906 and 1907. This first unit was started on March 22nd, 1907, and the first power used at the mines April 27th, and the plant has been in continuous operation ever since.

GENERATING MACHINERY.

The generating plant consists of a line of four pairs of 45-inch horizontal turbines in tandem, furnished by The James Leffel & Co., of Springfield, Ohio, direct connected to a 1500 kilowatt, 3-phase, 60 cycle, 6600 volt alternating current generator, at 180 revolutions per minute, furnished by the General Electric Co., also two 30 kilowatt, direct current exciter units, direct connected to two single horizontal, 20-inch turbines.

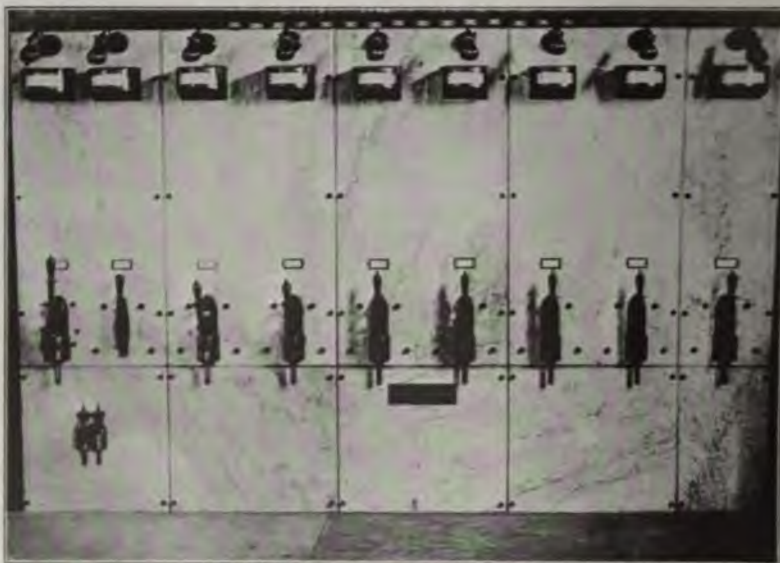


FIG. 16

Of the two commercial cycle systems used in this country, 25 and 60, the latter was adopted because the pumps had to be run at about 1200 revolutions per minute.

Since starting the first unit there has been installed a motor driven pump for delivering water to the three dwelling houses, provided for the operatives, a small motor compressor for cleaning the generators, and a motor driven exciter.

The 1500 K. W. generator built by the General Electric Co. is rated at 132 amperes with 660 volts. This machine has been run for ten hours with a current load of between 200 and 250 amperes and voltage up to 7300. At times the load was 275 amperes. It has carried these heavy overloads without giving any trouble whatever. The water-wheels have worked perfectly and the Lombard governor holds the speed as constant as could be desired.

There has been no trouble with "frazil"—or "anchor ice."

Recently the second unit has been installed, consisting of a duplicate line of water wheels, direct connected to a 2000

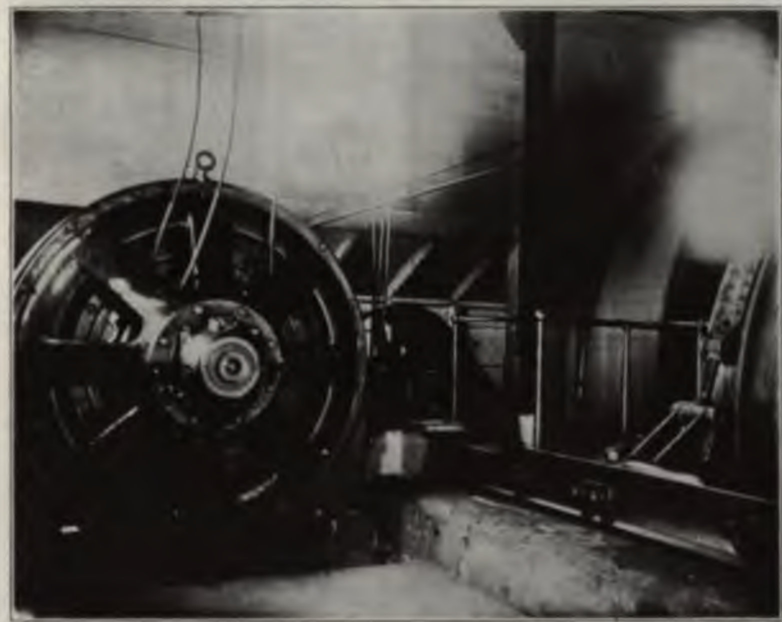


FIG. 17

kilowatt generator, furnished by the Westinghouse Electric & Manufacturing Co., which will be operated in synchronism with the first unit.

TRANSMISSION LINE.

Figure 14 is an outline map showing the river, the transmission line to the Vulcan mine, and the location of the substations.

For the transmission line No. 000 Brown and Sharp guage stranded copper wire is used from the power house to the junction pole, 00 stranded wire from the junction pole to West Vulcan and number four solid from the junction pole to East Vulcan.

The poles are seven inch tops, 35 feet long except at a few places across depressions where longer poles are used.

Locke porcelain insulators are used. These are tested to

FIG. 18

60,000 volts, and are good for a line voltage of 23,000 volts, three and one-half times the voltage now in use i. e., 6600. The wires are spaced three feet apart.

SUB-STATIONS.

There are at present two sub-stations practically the same; one at East Vulcan and one at West Vulcan. They are built of brick, approximately 20 feet long, 9 feet wide and 20 feet high. The following describes the West Vulcan station.

The transmission line enters at one end through three Locke porcelain insulators which are supported by slate panels one and one-half inches thick, 19 inches square, built into the brick work of the end wall. From these insulators the line is led through disconnector switches and choke coils (which are shown at the top of Fig. 15) to a high tension oil switch mounted in a brick cell (shown at the bottom of Fig. 15). Lightning arresters are connected to the line above the choke coils (shown in the center of Fig. 15.) From the high tension switch the current is carried to three step down transformers, which reduce the voltage from 6600 to 2200. Three 500 K.W.

FIG. 19

transformers are used at West Vulcan, three 300 K. W. transformers at East Vulcan.

The 2200 volt current is carried to the switch board shown in Fig. 16. The panel on the left is the sub-station panel. The larger handle on this panel operates, by a system of levers, the high tension switch in the sub-station. The smaller switch on this panel operates an oil switch through which all the 2200 volt current flows. Below these switches is a time limit relay which will open the first switch in case of a prolonged heavy overload. The two instruments on this first panel show the voltage and amount of 6600 volt current used at this sub-station. The other seven switches are feeder switches each supplying a certain motor or set of motors. Each feeder circuit has an ammeter showing the amount of current used on each line and an automatic release which will

FIG. 20

open the switch in case of a heavier overload than is desired. The point of release is adjustable. A ground detector hangs on a bracket to the right.

The switch board at East Vulcan is the same excepting that it has one less panel.

HOISTS.

One hoist at each mine is motor driven. They are of the double drum geared type. The hoist at West Vulcan has drums 12 ft. in diameter. The pinion shaft runs at 56 revolutions per minute, the drums at 17.3 revolutions per minute with a hoisting speed of 652 feet per minute. The motor is connected to the pinion shaft by a rope drive built by the Dodge Manufacturing Co. The large rope wheel is 22 feet in diameter and the motor rope wheel 42 inches in diameter using 24 turns of one inch rope, American system. It was impossible to get more than 25 feet between the centers of the

FIG. 21

motors and the pinion shafts, which necessitates a deflector pulley as shown in figures 17 and 18.

The motors are General Electric company's 2200 volt, 200 H.P. three phase, form M, induction motors running at a synchronous speed of 360 revolutions per minute. The fly wheel of the engine was taken off and the connecting rod of the engine disconnected from the crank pin. To change back to a steam driven hoist, it is only necessary to put on the connecting rod—fifteen minutes work.

The energy of the revolving parts, varies with the weight, the square of the diameter and the square of the revolutions per minute. The amount of energy in these parts i. e. rotor, deflector pulley, 22 foot pulley, pinion and two gears, is such that it requires as much current to get them up to speed in 30 seconds as is required to do the hoisting. These revolving parts are gotten up to speed before the clutch is thrown in, which is done gradually. The energy given out by these re-

FIG. 22

volving parts in slowing up from full speed to slip speed or full load speed, (which is 4 per cent less) is enough to accelerate the drum, skip, rope and load, thus giving no peak load in starting. At East Vulcan the skip carries 5800 pounds of ore with a total load of 14,400 pounds and the length of hoist is about 1250 feet of which 1050 feet is in a vertical shaft.

These hoists have been running over a year and the same fibre band on the friction clutch is still in service and in good condition.

Figure 19 shows the panel, with the oil switch and the ammeter, and below it, the controller. At the right and left of the controller are the hand wheels operating the friction clutches and the brakes. At the right of the oil switch is the hand wheel operating the throttle valve of the engine when using steam.

In new hoisting plants the steam engine would of course be omitted.

Back balance drums are to be used to counter-balance the weight of the skip or cage and the rope. There are to be two tapered drums for each skip or cage to be balanced, the rope from one leading to the hoisting drum, and the rope from the other leading to a counter weight in the shaft. By the use of tapered drums the varying weight of the rope is balanced so that the unbalancel load at any point is only enough to pull the drums around. Back balance drums on this principle are in use at the Republic mine.

PUMPS.

For pumping, three eight-inch turbine or centrifugal pumps are in use. Two are at West Vulcan and one at East Vulcan. They run about 1200 revolutions per minute and were designed to deliver 900 gallons of water per minute but they have a range of from 500 to 1250 gallons per minute each. The suction lift is about 20 feet and the discharge head including friction about 1275 feet. The pumps were built by the Henry R. Worthington Co. and are driven by 450 H.P. General Electric Co. 2200 volt induction motors.

These pumps are divided into two parts with four stages on each side of the motor as shown in Fig. 20. The suction is at the right from whence the water passes to the center of the first impeller (shown in Fig. 21) is thrown out at the circumference into a channel ring (not shown) and led by diffusion vanes (shown in Fig. 21) to the center of the next impeller.

It travels thus through the first section of the pump toward the motor from which it is led by a pipe to the further or left end of the second section. Here it travels the same course through four impellers, channel rings and diffusion vanes, again toward the motor. In other words, the water travels in opposite directions in the two sections of the pump. The motor shaft is connected to the pump shafts by split sleeve couplings, making a rigid connection between the pumps and

FIG. 23

the motor. This allows one section of the pump to help balance the end thrust of the other section. On the suction end of the pump the shaft is fitted with a marine thrust bearing (shown in Fig. 21.) On the other end is fitted a water step bearing. The impellers are of bronze and the channel rings and diffusion vanes of cast iron. The casings are of cast steel. The shaft is nickle steel 3¾ inches in diameter. Where it goes through the pump heads it is packed with a fibrous packing. At these points the shaft is protected by a steel bushing which can be renewed when worn, and there are brass bushings where it goes through the diffusion vanes. The hubs of the impellers are also bushed where they enter the diffusion vanes.

The quantity of water is varied by simply closing or opening a gate valve on the suction of the pump. The pumps when in good order with 900 gallons of water per minute have given efficiency tests as high as 66 per cent. This is from the current delivered to the motor to the water delivered at the top of the shaft.

The water is measured by means of a vertical knife edge orifice. At West Vulcan this is seven inches in diameter. The quantity of water flowing through an orifice varies as the square root of the head of water above the center of the orifice. For recording this head a Bristol recording water level guage is used, which records with very great accuracy a variation in head of one-tenth of a foot. The chart is a weekly one, 7 inches in diameter, so that every chart shows the actual amount of water pumped for that week. (Fig. 22). The water at West Vulcan has decreased from 1800 to 900 gallons per minute since the original estimate three years previous.

COMPRESSORS.

At West Vulcan two Ingersoll-Sergeant piston inlet, rope driven duplex compound compressors are installed—size 35¼ inches and 22¼ inches by 42 inches. The rated capacity is 3110 cubic feet of free air per minute. The rope wheels are 18 feet in diameter grooved for twenty-four one and one-fourth inch ropes. The motor pulleys are fifty-two inches in diameter. Deflector pulleys were required here also because of the short centers between motors and crank shafts.

One of the motors is a General Electric Co. 450 H.P., 2200 volt form L. M. induction motor running at 300 revolutions per minute synchronous speed. The compressors run at 70 revolutions per minute. The other motor is a Westinghouse Electric & Manufacturing company's 450 H.P., 6600 volt form H. F. induction motor at the same speed. This is the motor shown in Fig. 23.

These compressors have 10-inch gate valves in the low pressure discharge and 5-inch gate valves on the high pressure discharge both opening to the atmosphere below check valves, so that the compressors can be started with less than full load current even when one is already running and the air pressure is up in the receiver. After getting up to speed these valves

FIG. 24

are closed. The quantity of air is regulated by an automatic valve which closes the intake. This valve is moved gradually sometimes remaining in a partially closed position for a considerable length of time.

The East Vulcan compressor is a Laidlaw-Dunn-Gordon 18 inch and 29 inch by 24 inch duplex compound rope driven machine. The rated capacity is 2200 cubic feet of free air per minute. The rope wheel is 12 feet in diameter grooved for eighteen one and one-fourth inch ropes. The motor pulley is 50 inches in diameter. As the compressor wheel is only 12 feet in diameter it was not necessary to use a deflector pulley in this case.

The motor is a 350 H.P., 2200 volt, General Electric Co., form L. M., induction motor, running at 360 revolutions per minute synchronous speed. The compressor runs at 120 revolutions per minute.

The quantity of air is regulated by a choking controller which closes the intake entirely, but by the use of a dash pot it does it gradually. Ten to fifteen seconds are used to open or close this valve. The action is automatic and is controlled by the air pressure.

The motor rope drive and a part of this compressor are shown in Fig. 24, which also shows the East Vulcan switch board.

MISCELLANEOUS.

Surface tramming is done by 220 volt motors. The one at East Vulcan is geared to the tram plant. The one at West Vulcan is belted. The plants move the ropes to which are attached the cars that run between the shafts and the pockets or stockpiles. There is no power tramming underground as there is not enough ore on any one level to justify the expense of the installation.

The shops are run by 15 H.P. motors.

On surface 220 volt motors, varying in size from 5 H.P. to 50 H.P., are running laboratory crusher and pulverizer, concrete mixers, cord wood saw, lagging saw for splitting lagging, boiler tube cleaner, rock crusher, 40 H.P. hoist, and triplex geared pumps. A one horse power motor runs a horse grooming machine at the stable. The pump and principal shaft stations underground and all the surface buildings at the mines are lighted with a current of 110 volts.

The results of the application of electricity to the mine machinery has fully realized its expectations.

AUTOMATIC THROTTLE CLOSING DEVICE FOR HOISTING MACHINERY.

BY SPENCER S. RUMSEY, DULUTH, MINN.

Ever since the application of steam power to mine hoisting machinery, there has been a continuous line of accidents caused by over-winding. These accidents are always of a serious nature and owing to damage to shaft house or machinery, generally cause a cessation of mining operations for a longer or shorter period, and often result in loss of life.

Over-winding is caused sometimes by defective machinery, sometimes by the inattention or confusion of the brakeman, and often, where skips or cages are operated in balance, by the brakeman neglecting to reverse the engines, before opening the throttle for the next trip.

The means of automatically preventing over-winds has long been a subject which has received the most thorough consideration from mining operators and manufacturers.

One of the earliest devices was the automatic disengaging hook. This hook was fastened to the draw bar of the skip or cage and to it was attached the hoisting rope. In case of an over-wind, the hook would strike an iron plate held by timbers in the shaft house which would release the hoisting rope, and at the same time the hook would engage with the plate, thus preventing the skip or cage from falling down the shaft when the rope was released.

Another device, and one which is furnished with many of the larger hoisting engines, is a powerful brake which is automatically controlled by a gear or sprocket attached to the drum shaft, and is instantly applied when the skip or cage has reached a certain position in the hoist, usually just above the skip dump, or top landing of the cage.

This device is a step in the right direction, but should the brakeman be suddenly confused or disabled and not close the throttle, the sudden application of the brake when the engines were working under a full head of steam, would tend to seriously strain the shaft house and the machinery.

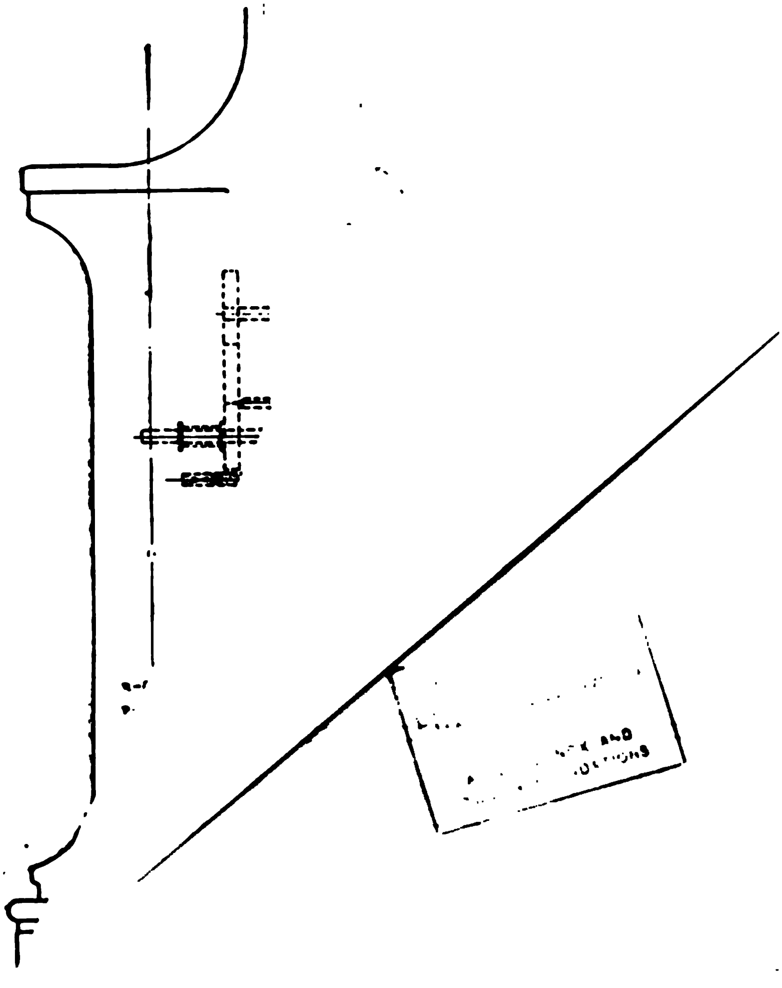
The head room above this skip dump is usually so low that the application of the brake occurs so near the danger point as to render its reliability somewhat in doubt and especially so should it be a little out of adjustment due to expansion or stretching of the rope, or should there be condensation in the brake cylinder tending to make its action sluggish.

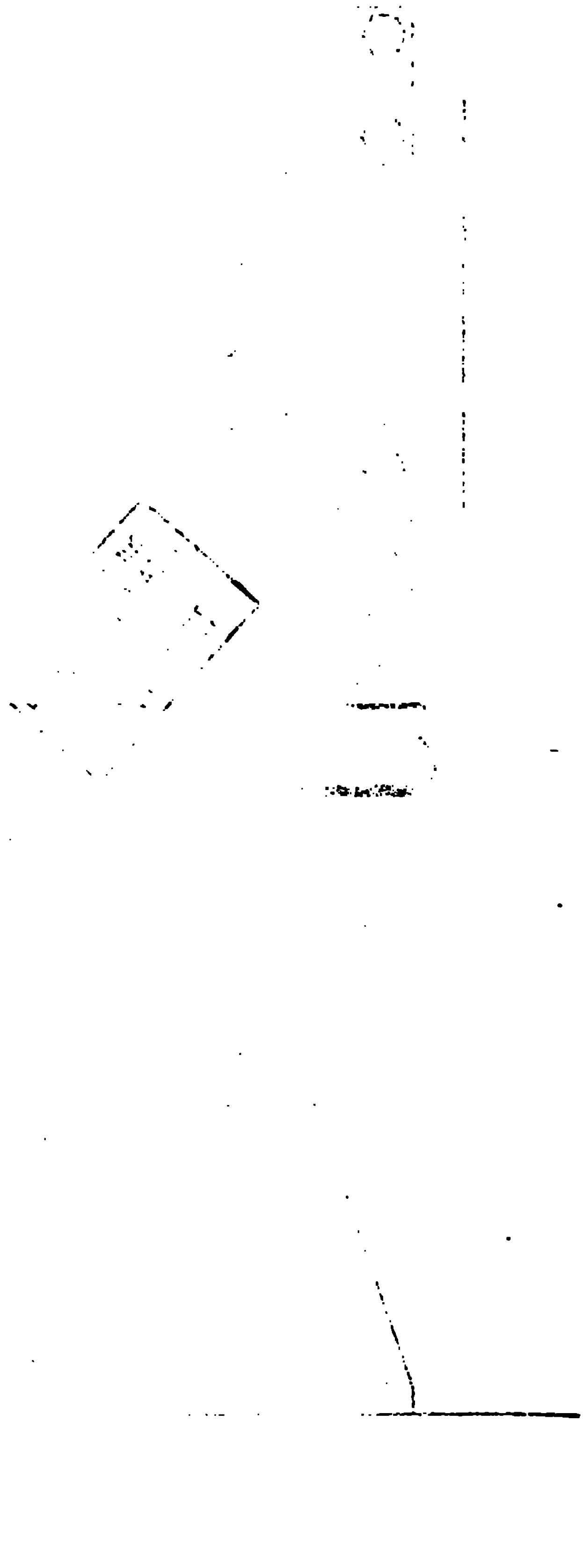
Attention was next turned to perfecting a device which would automatically close the throttle at a point during the hoist so that the momentum of the rising skip or cage would be just sufficient to bring it into the dump or to the top cage landing. If this device were perfected the skip or cage would not rise to the danger point, and overwinding would be practically impossible.

A great many different designs have been submitted during the previous years, but inasmuch as none of them would prevent overwinding from all causes and that most of them interfered with the rapid handling of the machinery, they never came into general use.

In the latter part of the year 1900 some time after the formation of the Oliver Iron Mining company, it was necessary for that company to purchase a new first motion hoist to operate the cages in "A" shaft, Pioneer mine, and the specifications required that this machine be equipped with an automatic device which would be a part of the hoisting engine and which would close the throttle at a point during the hoist so that the momentum of the rising cage would carry it to the top landing, thereby making it impossible for an over-wind to occur.

It is apparent to all that a number of devices could be





designed which would be operated by the drum shaft and which would close the throttle at any point desired; the difficulty was to provide for unlocking the throttle so that the engine could be run in the opposite direction and still keep the device absolutely automatic; and even if the above were accomplished, it still left the machine liable to an over-wind in case the engines were not reversed, after a hoist, before steam was turned on for the next trip.

While the manufacturers were studying over these complications, a new hoist was ordered for the Savoy and Sibley mines. This hoist was first motion and had two drums; one operating two cages with attached skips in the Sibley shaft and one operating two cages with attached skips in the Savoy shaft was to be equipped with an automatic throttle closing device. This still further complicated the problem.

The solution was provided by Mr. H. J. Wessinger, then mechanical engineer for the company. He planned to attach the throttle closing device to the reversing gear on the engines, which made it possible to open the throttle after the engines were reversed. Accordingly, the drawing, shown in Plate 1 was prepared, in which the designs of the manufacturers were rearranged and Mr. Wessinger's idea was embodied. In Plate 1 there is shown a screw shaft "I" which is rotated by a set of gears operated from the drum shaft. It is also given a movement of translation by the lever, 7, which is operated by the reversing gear.

"A" is a nut and wedge which engages the rollers "B" & "B." The nut is moved from positions 2 to 5 by means of the screw, but it is prevented from revolving by a guide shaft; the wedge lifts the rollers "B" & "B", thereby moving the roller-lever "C" & "C", closing the throttle through the connections.

At the beginning of a hoist the nut and wedge "A" is at position 3. During the hoist it is moved to position 5, raising the roller-lever "B" "C" which closes the throttle and locks it, making it impossible to open the throttle until the engine is reversed. When the engine is reversed the nut and wedge is moved from the position 5 to 4 which releases the throttle. The throttle is opened and the return hoist is made, and the nut and wedge travel to point 2, where the throttle is again closed. When the engine is reversed the nut and wedge is moved to point 3, releasing the throttle, and the process begins over again as above described.

The manufacturers were provided with this drawing and the throttle closing devices which were furnished for the Pioneer "A", Savoy-Sibley, also Pioneer "B" and Aragon No. 5 hoists were the same in principle as Plate 1, but differed somewhat in the details. The arrangement of shafts and drive was altered and two wedges were used instead of one and one roller-lever instead of two. These hoists are also provided with small auxiliary throttle valves, which are operated by treadles and are independent of the throttle closing device. They are used to aid in raising the skip into the dump should its momentum be insufficient. The size of these valves is purposely small to prevent the engines being operated except at a very low speed.

The hoists mentioned above have been in operation several years and the throttle closing devices have worked very satisfactorily. They are regularly tested and have always been found reliable, and in several instances are known to have prevented accidents.

They have given such general satisfaction that it is the intention of the Oliver Iron Mining Co. to install them on all new plants and also on a large number of old ones.

The devices furnished for the above hoists are complicated and the design has since been simplified. The throttle closing device as designed, and now used by the Oliver Iron Mining Co. is described below and illustrated by the following plates: Nos. 2, 3 and 4.

Plate 2 shows the general arrangement of a throttle closing device as applied to a direct acting hoist for the Mesabi range. In this plate you will note the lead screw "S" which is supported by boxes cast on the sole plate "E". The lead screw is revolved by a sprocket wheel "A" which is driven from the drum shaft by a sprocket chain. This screw is given a movement in the direction of its axis when the engines are reversed by means of the mitre gears "H" which are operated by the reverse shaft, lever "F" and connections "G". The screw has a feather key at the driven end which causes it to revolve with the sprocket wheel but permits it to slide in the hub of the sprocket wheel whenever the engines are reversed. "M" & "N" are shoes which are moved backward or forward with the revolution of the screw but are themselves prevented from turning by a guide on the sole plate.

The wedges "W" & "V" are fastened to the shoes and engage the roller "B", which is attached to lever "C", raising the latter and closing the throttle through the connections. To illustrate the operation of this device, we will consider the reverse lever in a position so that the engines will run under. The left hand or over wound rope is hoisting and the right hand or under wound rope is lowering. The wedges are at positions "W1" & "V1", the throttle valve is unlocked and may be operated by the hand lever.

The throttle is now opened and when the skip has been raised to the point where the steam should be completely shut off, wedge "W" has moved to position "W2", raising the roller "B" and lever "C" which closes the throttle. The throttle is now locked closed and cannot be opened until the engine is reversed. Wedge "V" has moved to position "V2".

When the reverse lever is thrown over it operates gears "H", lever "F" and connections "G", pulling the lead screw and shoes until wedge "V" is in position "V3" and wedge "W" in position "W3", which releases the roller and unlocks the throttle. Steam may now be turned on for the return trip in which wedge "W" moves to position "W4" and wedge "V" to position "V4" which closes and locks the throttle.

The engine is again reversed and the wedge "W" moved to position "W1" and wedge "V" to position "V1" which unlocks the throttle and the process may begin over again as above described.

If for any reason the momentum of the skip should not carry it into the dump the by-pass or auxiliary throttle may be opened by the hand lever "L".

The size of the auxiliary throttle is such that it will admit only enough steam into the cylinders to operate the hoist slowly until the desired point is reached.

Plates 3 and 4 illustrate the details of construction of the various parts of the above device and are sufficiently clear as to need no further explanation.

The throttle closing devices which are being prepared for deep mines are identically the same in principle and differ only in the length of screw and sole plate.

STRUCTURES OF THE MESABI IRON ORE.

By N. H. Winchell, Minneapolis, Minn.

After such a strenuous day as we have had I do not feel sure that I shall be able to say anything as to the structures of the ores of the Mesabi range which will keep your attention. I have, however, a paper which was written about a year ago which I will give in abstract.

It is nearly sixteen years since I visited Virginia, or rather the spot on which Virginia was destined to be built. My party camped in this vicinity somewhere. Some of the first openings were then being made in the ore bodies. After a careful review of the field-facts at this place and at other points further east bearing on the nature and origin of the ore formation of the Mesabi range, I reached the following conclusions, which I published in my report for that year:*

1. The ore is not explained satisfactorily by any theory that has been proposed.

2. The ore has resulted from a profound alteration of some pre-existing rock.

3. The rock was of a peculiar composition, or

4. It has passed through a peculiar and unusual physical history.

Since then other work has prevented me from visiting again the mines of the Mesabi range.

Prior to the opening of the great mines on the Mesabi iron range it was rather difficult to form opinions as to the grand structures that the ore possesses. Some of the great pits are

*Twenty-first annual report of the Minnesota Geological Survey, for 1892, p. 134.

now about 200 feet in depth and extend in a direction parallel with the strike of the rocks, something more than an eighth of a mile, affording a magnificent opportunity to study the ore and the structures, and the relations that it bears to the associated rocks. On the occasion of the late (1907) proposed meeting of the Lake Superior Mining Institute at Duluth (which was abandoned on account of the miners' strike) the writer enjoyed a revisit to the Mesabi range, which he had longed for ever since the close of the Minnesota Geological Survey. Not aware that the meeting had been postponed until his arrival at Duluth, he resolved to continue his trip alone to the mines on the Mesabi range. Owing to the great strike everything was quiet, and the dust and smoke which usually rendered such a visit unpleasant were wanting. It had rained copiously the previous night. The ore structures were washed clean. Three days of leisurely examination were given to the open pits at Hibbing, Virginia, Eveleth, Biwabik and Mountain Iron. This paper is designed to present some of the facts observed at those places.

HIBBING.

The celebrated Mahoning open mine was examined only along the north and northeasterly sides. The average grand dip is to the south. At the west end, on the third bench, in the face of the pit,* the ore section is composed of ore in two different structures; these structures alternate in strata that are evidently such as would be formed by water deposition: (1) fine grained ore in strata that are mostly continuous and from half an inch to fourteen inches in thickness, (2) harder, i. e. firmer, ore, in lumps and broken layers which are about four

*In excavating the ore with steam shovel the work proceeds by benches, separated from each other vertically about 20 feet, that being the depth which the shovel can easily excavate. The railroad tracks run into and about the mine on these benches. In some of the open mines these benches succeed each other to the number of six and eight, if the ore is firm; if the ore is uncemented a single course of the steam shovel may excavate, as at the Mountain Iron mine, a vertical depth of a hundred feet, as it crumbles naturally to the bottom of the pit.

inches thick. These are not strictly continuous, but are made up of smaller constituents mingled with much fine ore presenting a conglomeratic aspect. When closely examined the harder layers prove to be mainly composed of ore, which, however, is apt to be lean, and to pass to a kind of taconite, or a gray massive and limonitic ore.

FIG. 1. Stratification at the Mahoning Mine.

Ropy Structure. Passing eastwardly along this bench the writer observed and picked up a piece of ore which on one side presents a parallel series of ridges or convolutions that resemble the ridges formed on the upper surface of a lava flow designated "ropy structure". (Fig. 2). It is about six inches long and about five inches wide, a fragment, evidently, of a larger surface. It shows ten or eleven of the ropy elevations running parallel with the length of the piece. Such ridged upper surfaces of lava flows are seen in the trap beds of the Keweenaw-

FIG. 2. Ropy Structure.

an, and have been represented in the final report of the Minnesota Survey (Vol. V, p. 237)

Sedimentary Shale. At the eastern end of the Mahoning pit the rock (and ore) grades into red shale which is very plainly sedimentary. This is in some of the highest of the strata exposed at this mine, so far as observed. Some of it might be called a low grade ore. Similar red shale is a common feature in the Keweenawan formation.

Volcanic bombs? Near the same place, but further west, in walking along the railroad track on the second bench, I observed several roundish masses, rolled down the talus to the foot of the cut. They were from three to ten inches in diameter, somewhat flattened. They appeared to be volcanic bombs. On being broken one was found to be composed of impure taconitic ore, but about one-half of it was spongy, or vesicular. Time was short. From about a half a dozen that were visible within about 30 feet one of the smaller ones was taken (Fig. 3). It had been broken away on one side disclosing a hollow centre.

FIG. 3.

Globular Forms. Further west was noted a structure that appeared to be similar to that seen and described on Grand Portage island in the trap composing the upper portion of that island and described in Vol. V of the final report of the Minnesota Survey. This is characterized by *balls* due to the manner of solidification and subsequent disintegration of the trap flow (Fig. 4.) On weathering these globular masses are made apparent and can be gathered in considerable numbers on the level surface of the lava. At Grand Portage island they are about as large as a rifle ball, and smaller, but at the Mahoning mine the analogous masses are as large again, and consist entirely of ore. They are often adherent by a cement which

FIG. 4.

crumbles out leaving the balls projecting. This globular structure was seen at other mines.

VIRGINIA.

Conglomerate. The Buffalo mine (also known as Oliver mine) is the only open pit at Virginia. At the west end is a lot of breccia or iron ore, a part of the mine formerly called Lone Jack. The writer has assigned this conglomerate to the bottom of the Cretaceous but he does not now feel satisfied entirely with that conclusion. From what is now known of the origin and structures of the Mesabi ore it is more reasonable to expect that this breccia-conglomerate is a constituent part of the Mesabi formation. Without having made any new observations on this ore worthy of being mentioned here, one or two features already published may be recalled.* (1) It is entirely made up of ore like that of the region, but some of it is of low grade and apparently results from a rock like taconite. (2) Some of the pebbles have an irony crust harder than the interior and from the crust toward the centre there is an increase of coarseness of texture, even becoming spongy, or somewhat layered with imperfect concentric shells. Some of the larger pebbles are of taconite.

This entire absence of quartz and granitic materials shows that the rocks of the nearby Giant's range did not contribute to its formation, thus differing remarkably from the conglomerate that lies at the bottom of the Animikie, and from all known conglomerates at the bottom of the Cretaceous. The structure of the individual pebbles, which indicates a progressive change from the surface to the centre, is like that of the individual grains of fine ore which have resulted from a similar progressive alteration from the green substance later called greenalite. Except that the ore of the Lone Jack is of lower grade this conglomerate is similar to that of the Mountain Iron mine.

Jointed dike-like mass. Directly north from this breccia, the iron and its accompanying beds of impure ore are tilted almost to verticality. In the midst of these fine grained, nearly vertical, strata is a conformable sheet which is coarser grained and firm, from which the soft ore crumbles away allowing it to stand out conspicuously, presenting the outward aspect of a jointed dike, with an exposed face toward the south which extends about 30 feet, and about four feet high. Its lower part runs into the talus. Its thickness is about two feet, but at each end it becomes thinner and grades into the surrounding ore.

*Twenty-first annual report of the Minnesota Survey, p. 128.

The grain of the ore on the north side is immediately fine and dense and in thin sheets about half an inch thick, easily broken. The jointed southern face is represented below. (Fig. 5.) The sudden appearance of this curiously jointed mass, contrasting with the crumbling strata of ore above and below it, seems

FIG. 5.

easily explicable on the supposition of a surface lava flow cracked by shrinkage in the midst of sediments accumulating by the ordinary methods of oceanic forces, the whole subsequently highly tilted—and that is apparently the only plausible explanation.

Purgatories and Amygdaloidal Structure. Eastward from this jointed mass, the dip continuing about 60 degrees toward the south, there is a confused mingling of heavy taconitic beds with thin beds. At a casual glance the appearance suggests a line of fault and its breccia, the thin beds being mostly on one side, but having a steeper dip than the massive beds. The structure is probably due to the shrinkage of the rock which has been most altered, away from parallelism with the rock less altered, making an apparent non-conformity. The same appearance might be produced by the flow of a mass of lava over a cliff, becoming porous, thin bedded and non-conformable on the rocks of the cliff, and dipping at a higher angle. These irregularities appear extensively along the north side of this mine, the whole formation becoming twisted and crumpled, the heavy beds fading out, and in some cases also having crumpled, thin layers between them. Underneath all this, which has a thickness of 50 feet more or less, is a lot of good purple soft hematite, having the same steep southward dip, which is mined extensively. The face of the bluff, viewed at a distance, has the suggestive appearance structurally, of the trap bluffs along the north shore of Lake Superior, even to the *purgatories.*

Some lumps of the best ore seem to have been originally *amygdaloidal.* They are pure and purple ore now, but porous and varied with blotches of ore that is plainly somewhat hydrated.

Remnants of Fluidal Structure. Along the north talus large blocks have fallen since the cut was made, most of these are joint blocks of taconite, but some of them, while firm taconite within are covered at the ends where the structure has been broken or rotted away, with a bristling lot of thin scaly projections which grow out from the rock itself. These stand parallel with each other and with the bedded structure of the mass. They are evidently remnants of the more durable parts of a structure which once penetrated not only the taconitic blocks themselves but also the rock surrounding them, passing into the general ore body, and can be referred to the former existence of a fluidal structure in the whole rock, the projecting sharp scales, or sheets, being the result of variation in the original obsidian. This supposition is perfectly concordant with another structure seen on these same scaly blocks, namely the bullet-structure in the form of irregular balls and small shapes which are on the upper sides of these masses, supposed to be analogous to the globular structure already mentioned, due to the disintegration of the surfaces of lava flows, such as seen on Grand Portage island in the Keweenawan.

EVELETH.

Fayal Mine. The ore in general structure resembles that of the Mahoning mine. At the west end it is approximately horizontal, much stained with limonite and thin bedded, but with taconite "horses" which seem to be simply more silicified conformable patches in the iron mass. These "horses" change horizontally rather abruptly into the surrounding ore, becoming thin bedded, the rock then sagging down a little by reason of shrinkage. The general dip is toward the S.E. and is most distinct at the east end of the pit. The bottom of the pit at the east end is in a great mass of purple ore which is pure, fine and cheaply taken out. There are distinct colors of the mass of the ore at different points, viz: yellowish (mixed with black, red and purple): hematite red; and purple. The yellow color is most frequent along the upper portion, and is probably due to atmospheric hydration.

The smooth, wavy, upper surfaces of some of the fallen taconite blocks suggest the contact surfaces of trap layers seen along the Lake Superior shore, say, of the "Two Harbor rock". A thin scale, or two or three of them, somewhat more ferruginous, usually, or uniformly, cover the upper and lower surfaces of such fallen masses. The upper surfaces are not crosscut by joints but are simply undulatory or broadly mammillated. They do not indicate lava-flow surfaces but a deep seated sheeting. "Purgatory" holes in the bluffs are not uncommon, eight being visible from one point, looking west.

Biwabik Mine. Several quartz veins which are crumbling cut the ore, running nearly vertical, the width in one instance reaching ten inches. *Balls* of disintegration are here seen, like those already mentioned under *globular forms.* Some of them are detachable, and some of them run deep into the ore. There is here also a peculiar *breccia* which seems to be the same as that described long ago by me at the Cincinnati mine. Later this breccia was seen again on the old dump of the Cincinnati, where also was seen the *ball* structure already mentioned.

The bulk of the ore of the Biwabik is apparently not from a sedimentary rock, although it grades into a sedimentary structure. The yellow ore extends to the very bottom of the pit, but appearing in patches, somewhat alternating with red. The quartz veins probably antedate, or are coeval with, the formation of the ore. White kaolinic deposits were later than the ore. They embrace angular pieces of ore.

Igneous Sheeting Planes. The heavy fallen blocks, which consist of ferruginous taconite or lean ore, present a remarkable common and very suggestive feature which, though noticed before, did not appeal to me with such force as here. A large number of rough blocks, from 1½ to 2½ feet thick, lie on the sixth bench. (There are nine benches, each about 20 feet high). These blocks are sometimes four feet across along the extreme diameter, but vary to all sizes downward. When they have not been split in quarrying or in falling, their upper and lower surfaces are wavy and continuously coated over with a thin scale of fine-grained ore, though the mass is generally composed of taconite, or a coarse-grained, brown impure ore. These thin scales are sometimes two or three in number, indeed usually are, and are from ½ inch to 1 inch thick each, the whole scale portion grading into the general mass. They generally are denser and better ore than any other part of the blocks on which they occur. These are probably not the rapidly formed contact surfaces of successive flows of trap rock when molten but deep-seated bedding planes. It is these fine grained scales that constitute the undulating or coarsely mammillated surfaces already mentioned, and which crack by a fine jointing into small angular bits ½ inch square or less, and so become loosened from the parent slabs. Sheets of trap rock in the Keweenawan are thus characterized at several places on the north shore of Lake Superior.

Remn.nts of Green Stone. Associated with some of the kaolinic deposits at the Biwabik, or at least in the dump of the mine, are pieces of green original rock much altered toward kaolin. Some of it is stained with iron oxide but a noticeable amount of it still retains what was probably its original color, indicating that it was at first of a basic nature and igneous origin.

MOUNTAIN IRON.

Oliver Mine. Here is an immense open pit, second, so far as I have seen, to the pit of the Mahoning. It runs about east and west and probably includes several of the original "locations" noted by me several years ago.

Amygdaloid. Along the south face, near the top, just under the stripping, is found much taconite, rather evenly bedded and jointed in angular blocks so as to come out in pieces six inches to ten inches in diameter. The blocks have the smooth scales of more pure iron separating them and coating their bedding surfaces when separated horizonally, already mentioned at the Biwabik mine. On searching here for amygdaloidal parts I found but little. But instead I found beneath these thin scales of iron a blotched irregular taconitic belt, sometimes coarser, about two inches thick. This passes toward the centre of the block, into the usual gray taconite. Sometimes this irregular belt is wanting and the iron scale is cemented upon taconite.

Some of the talus pieces are plainly pieces of amygdaloid, converted to ore and kaolin. The amygdules now being hematite and the rock mass itself being kaolinic.

FIG. 6. Amygdaloidal Structure. Mountain Iron.

Indeed, many of the taconite blocks show, under the iron scale, a prevailingly white color, which on closer examination appears to be due to a pisolitic distribution of white kaolin; and this kaolin also sometimes is sprinkled more or less through the iron scale, and it goes deep within much of the taconite. It forms sometimes thin sheets both in the red ore, by which it is not stained, and in the taconite.

At the dump, near town, south side of the pit, has been thrown very much amygdaloidal rock. The mesh is here spongy quartz, passing to light colored taconite. It is associated with pisolitic taconite and with brown-gray limonitic taconite. Some of the masses of this amygdaloidal rock are more than a foot in thickness. They have the iron scale on at least one side. The dump extends about 75 feet, and is 18 feet high, the largest pieces having rolled to the foot. On looking all over this pile not a piece of amygdaloid was found with the iron scale on both sides. Either they have no such scale or they show it on only one side. The former condition being most frequent. This is in keeping with the well-known fact that in case of a lava flow the amygdaloidal structure is formed

FIG. 7. Quartz Mesh. Mountain Iron.

on cooling mainly in the upper part of the mass, and that it fades out downward into the body of the non-amygdaloidal rock. It is also in keeping with the supposition, already stated, that the iron-scale expresses the plane of contact of deeper internal sheeting, rather than lava surfaces.

In order to explain the prevalence of quartz forming the mesh in some places and kaolinic rock in others it seems necessary to allow that in a chemical transformation such as that which has formed this ore, the circumstances of environment must have been such that, while the alkaline earths and alkalies were being entirely removed in solution, quartz and alumina were not wholly removed, but were accumulated, now here, now there, in accordance with the demands of physical and chemical conditions. The iron ore, therefore, is no more a concentrate from the original rock than are the kaolin deposits and the quartz veins and the quartz-filled vugs. Of the last many large masses are seen at Mountain Iron in the form of crystals and coatings in cavities from a foot to four feet long; the longer diameters lying in the direction of the structure, and sometimes as much as a foot in thickness.

Conglomerate. The peculiar conglomerate occurring at the Lone Jack mine, at Virginia, has already been mentioned. When this iron range was first examined by the writer, and this conglomerate was encountered, it was presumed that the Lone Jack conglomerate was probably a part of the basal beds of the Cretaceous; but in the light of what was seen lately at Mountain Iron mine it is allowable to refer it to the age of the iron ore formation. From limited field examinations, and from microscopic study of samples collected by the Minnesota survey, it was shown that a breccia and even a conglomeratic structure is found to be the extreme end term of the fragmental materials of which an obsidian sand was the other. At the Mountain Iron mine this broad generalization finds unequivocal confirmation. Here a conglomerate stratum estimated at about 200 feet in thickness, (so far as observable) constitutes a principal part of the ore as now mined. It rises, with a gentle dip, from below taconite and other kinds of rock and ore, at the eastern end of the pit, to the drift stratum lying on the top, and it extends at least to the bottom of the mine. It is nearly all composed of fragments, more or less rounded, but still cemented by occasional patches or layer-like masses of iron not conglomeratic. It is all loose and easily mined. The original pebbles are from half an inch to two inches in diameter, and their forms are obscured by alteration and by cementation. The ore is ochreous. It is easy to imagine that by a reduction in the size of these pebbles we would have the "soft ore" proper, i. e., the sandy ore.

If the iron formation was originally a mass of trap rock, constituting a great formation analogous to the Keweenawan, as believed by the writer, it appears to have embraced large strata of conglomerate made up of rock of its own kind. Such

FIG. 8. Pebbles from the Conglomerate. Mountain Iron Mine.

conglomerates are a well known feature of the Keweenawan.

To recapitulate: The iron formation of the Mesabi range embraces many of the structures that are easily referred to volcanic action and to igneous eruption, such as: ropy structure, volcanic bombs, globular forms of weathering, jointage identical with that formed in the cooling of trap rock, purgatories, amygdaloid, fluidal structure, contact planes, remnants of original basic greenstone and thick beds of conglomerate composed of the same rock as that of the associated strata.

To a person who is familiar with the Keweenawan along the north shore of Lake Superior, it is the most obvious inference that these structures can be formed only by igneous extrusion.

In conclusion I wish to say that I present these suggestions tentatively. I may be mistaken as to the interpretation of the structures described. Having already, in earlier publications, explained the Mesabi iron ore on the theory that it has resulted from a change in igneous rock, I may be more inclined to see igneous features than a disinterested observer. Whatever may be the final conclusion of geologists, however, whether from igneous rock or from—I do not know what kind of rock—I shall be satisfied when the problem is settled.

If opportunity and time permit it is my intention to make further microscopic examination of the minute structures of the Mesabi ore.

ACETYLENE AS AN UNDERGROUND LIGHT.

By William F. Slaughter, Republic, Mich.

Up to the present time, acetylene has been a failure as an underground light. This failure has been due, I believe, to the inconvenience caused by the size of the lamps used. The lamps were too large and too heavy to be worn on the hat, so it was necessary either to carry them in the hand or hook them to a button hole in the front of the coat, both of the latter means being inconvenient at times; as, for instance, in going through low openings, or climbing ladders.

I have been using "Baldwin" lamps for six months in my surveying work underground, and find them very satisfactory. The lamp consists of a water tank on top into which is screwed the carbide container. A small pipe projects from the bottom of the water tank into the carbide container, and a wire of a size to permit just the required amount of water to flow down the pipe and onto the carbide, passes through the pipe, projecting above the top of the lamp. If the tube becomes blocked, it can be cleaned by rotating the wire. When the burner gets blocked, it is cleaned out with a small wire which is carried on the lamp. There is an extra bottom or carbide container furnished with each lamp. This bottom has a screw cap to keep the carbide dry, and when wanted, can be exchanged for the one in the lamp.

When water is added to the carbide, the reaction gives calcium oxide, CaO, and acetylene C_2H_2. The acetylene, when ignited in contact with the air, changes with the oxygen in the air to carbon dioxide and water. $C_2H_2 + 5O = 2CO_2 + H_2O$.

I compared the light with a mine candle, one of the kind known as "eights", and find the light about equal to that given by one candle. A test was made to see which consumed the most oxygen. The candle was placed in an inverted carboy, capacity about one and one-half cubic feet, the neck being under water, thus giving a water seal. Not being able to get the lamp in the carboy, the gas was conducted through a rubber tube to a burner inside. From several trials, it was ascertained that the acetylene uses about one-fifth as much oxygen as does a candle.

COMPARATIVE COST.

Candle at 9 cents per pound cost 2.81 cents for ten hours.

Carbide at 5 cents per pound costs 1.95 cents for ten hours.

This means that the acetylene saves one-third the cost of the candles.

ACETYLENE LAMP.

DISCUSSION.

Mr. Dickinson: I believe the lamps are now used in the Saginaw mine, on the Menominee range, for lighting instead of candles.

Mr. Lane: In my use of the lamp the flame has been regular from the start to the time the carbide is consumed; the water is fed through the bottom of the carbide.

MR. UREN: How much carbide is used per shift in the lamps at the Saginaw mine? Mr. Dickinson stated that he had no figures.

MR. MCNAIR: My experience during the last fifteen months, in making tests of lights shows that where there is a deficiency of 16 or 17 per cent. less oxygen than noraml atmosphere, where the miners' candle will burn low, the acetylene lamp burns as brightly, as far as ordinary observation goes, as it does in open air, which confirms Mr. Slaughter's statement.

Mr. Cole asked Mr. Hearding to give his experience in connection with the lamps:

MR. HEARDING: We used quite a number at the Adams, in drifts, on account of bad air; we find the lamp will burn free where you cannot use a candle, and remain lit; they require a little attention by the miners in seeing that the water feeds properly to the carbide and outside of that there is no difficulty; they seemed to be satisfactory in lighting drifts where the air is particularly bad.

MR. SIEBENTHAL: I might say that we expect to use these lamps instead of candles in close places; we have none in use at present. The carbide costs about 5 cents per pound and about 2 cents per shift will provide carbide for one of these lamps.

MR. STOCK: They are used to some extent in the anthracite mines of Pennsylvania. The objection given by Mr. Hearding is the same there; the lamp requires to be picked out and kept clean. As soon as the men learn how to use them there does not seem to be any trouble.

MR. YUNGBLUTH: What is the cost of the lamp?

MR. SIEBENTHAL: About 75 cents each; of course you can get them in all sizes. This lamp will run about a shift, making allowances for the noon hour.

MR. VOGEL: At the New Jersey Zinc company they use these lamps. We went up in a 350 foot raise where the air was bad and the lamps gave good satisfaction. I was informed by the management that it costs them about 2 cents per shift for carbide.

THE STANDARD BOILER HOUSE OF THE OLIVER IRON MINING CO.

By A. M. Gow, Duluth, Minn.

Before considering in detail the plans of the standard boiler house of the Oliver Iron Mining Co. the conditions which it was designed to meet should be understood. In advance it was seen that a large number of boiler houses would have to be erected, and to avoid the labor and expense involved in a multiplicity of design it was important that some standard plan be adopted that would lend itself to the variety of conditions to be encountered at the various mines. In other words, while it was necessary to adopt a standard, the standard must have a great degree of elasticity and adaptability. The word "standard" as used in this connection does not mean "duplicate"; each separate installation presents its own peculiar conditions of location and size that must be taken into consideration, but certain features of construction and practically all matters of mechanical detail have been so standardized that the design of a new boiler house consists largely in assembling plans that have already been worked out. To begin with, it was necessary that the building should be such that it could be readily erected by available labor and be reasonably free from danger from fire; the boiler should be suitable for 150 pounds working pressure and of that type, which in the judgment of the chief engineer, was least liable to give trouble and could be maintained at least expense, while maintaining maximum efficiency; the setting should be adapted for use with from two to six boilers in battery and capable of increase or decrease; the appurtenances must be as simple and as near "fool proof" as possible to make them; the entire plant must be of reasonable cost, thoroughly efficient and free from mechanical complications and "frills," while fully able to bear criticism from the standpoint of good engineering.

At the outset, therefore, it is evident that the problem that confronted the engineer, Mr. H. J. Wessinger, was a very different one from that which presents itself when a central power station of from five to 20,000 horsepower is to be designed, with a lease of life supposed to be everlasting, the whole to be under the immediate supervision of a chief engineer with an abundance of skilled labor. The boiler house of the Oliver Iron Mining Co. is not to be judged by the standards applicable to such installations. It is essentially and primarily a boiler house adapted to the needs of the company. How well the plans have met the requirements may be judged from the fact that within the last six years about thirty boiler houses have been built, containing from two to six boilers each, and no essential changes made in the general designs. The members of the Institute will appreciate what a saving of time and labor in the engineering department has been effected by this system and how the work in the field has been facilitated.

This same system of standardizing working plans has been followed in the design of dry houses, oil houses, office and warehouse buildings, captain's offices, small machine shops and engine houses. As said before the word "standard" does not mean "duplicate." But in all these buildings a certain type of construction is followed, the details remaining the same, so that the work of designing a new building consists largely in assembling existing plans, already worked out, and adapting them to the new location.

The subject will be considered under the following heads: The boiler; the boiler setting; the fronts and appurtenances; the stack and breeching; the building, coal trestle and elevator; costs. All plates are reductions from working drawings.

THE BOILER.

The standard boiler is a 72"x18', horizontal tubular, with

½″ shell, 9-16″ heads, designed for 150 pounds working pressure. The specifications are practically those of the Hartford Steam Boiler & Inspection Co. somewhat condensed. The exact length over all is 17′-11-½″ that 18′ tubes may be used. Tubes are 4″ Shelby steel, spaced wide in the center and away from the sides. A manhole is provided in the front head and four 1½″ through rods, upset at the front end and secured by inside and outside nuts, stay the heads below the tubes. The longitudinal seam is double butt strap, quadruple riveted, having an efficiency of 94 per cent. Upon the boiler are located three cast iron nozzles, faced and drilled for 1902 standard flanges; one 4″ for feed and auxiliary steam connection; one 7″ for main steam connection, and one 4″ for safety valve. The blow off connection is a pressed steel flange threaded for 3″ pipe. Special attention was paid to the matter of bracing the heads and 22 braces provided, carefully spaced, no brace to be less than 3′-6″ long or less than 1″ in cross section. Approximately 100 boilers have been built to these plans and specifications and no reason found to alter any of the details. The boiler is shown on Plate 1.

The question has often been asked why this type of boiler was adopted and not some approved type of water tube. It is not within the province of this paper to discuss the relative merits of different types of boilers. Suffice it to say that it will not be admitted that, necessarily, a water tube boiler is a more economical steam generator than a horizontal tubular. The horizontal tubular can be set, removed and re-installed with much greater ease and economy than can a water tube, and this matter of removal is an important one, considering the life of the plants. The installations are, comparatively speaking, small, rarely exceeding four boilers to a battery and the matter of ground space is not one of serious moment. The objections raised to this type of boiler by the water tube advocates are the difficulty of cleaning, the liability to bagging and the danger from explosion. The water at the mines of the company is almost uniformly good; with good water and reasonable attention tubular boilers can be and are kept clean. As to bagging, the records show that with the hundreds of tubular boilers in use by this company, about one boiler, per hundred, per year, bags. Serious bags, which cannot be driven back and require either a new sheet or a patch, have amounted to less than one boiler in two hundred, per year. As to the danger from explosion, it will not be contended that this does not exist. Boiler explosions do occur and in the most unaccountable manner. By constant and careful inspection it is hoped to reduce this danger to a minimum. But the results from burst tubes in water tube boilers have been very serious according to the records of the insurance companies, which records do not show, by any means, that their losses are confined to horizontal tubular boilers. This company has in operation today about one thousand boilers. This includes firebox, marine, horizontal tubular and four different makes of water tube boilers. A fairly good opportunity is certainly afforded for judging of their relative merits. In all new plants the horizontal tubular is being installed.

THE BOILER SETTING.

The setting is shown on Plate II. Regardless of the number of boilers in battery this drawing is followed. It has been repeatedly used for batteries of from two to six. The boiler is supported upon lugs and is not suspended. This feature has been severely criticised, for as a rule, an advocate of the suspended setting can see no merit whatsoever in the supported setting. A first class, suspended setting is, no doubt, superior to a poor, supported setting, but it will not be admitted that there is anything inherently wrong in supporting a boiler upon lugs, resting upon the side walls. The claim that the walls of a suspended setting are less liable to crack and bulge than those of a supported setting is not borne out by experience. Walls that are heavy enough to reduce radiation to a minimum are abundantly strong to bear the weight of a boiler. Lighter walls are not desirable. Having provided heavy walls for the purpose of retaining the heat there is no reason why they should not serve the additional purpose of carrying the weight of the boiler. The advocates of the suspended setting place great stress upon the idea that it is almost impossible to make the four lugs bear equally, and as a consequence, unknown and torsional strains are introduced. There is some truth in this contention; but admitting that the weight on each lug is not equal it remains to be proven that the strains thus introduced are of any material consequence. The boiler is sufficiently strong to bear such torsional strains even if supported upon but two diagonally opposite lugs. The suspended setting does not lend itself readily to increase or decrease in the number of boilers in the battery, and this is an important consideration with the company. Take it all in all, the introduction of columns into the side walls and overhead supporting beams involves elements of cost and inconvenience which are wholly unnecessary and do not give adequate returns.

It will be observed that the distance from the grate bars to the boiler shell is 36″; that the bridge wall is low and merely serves to prevent fuel being pushed off the grates; and that there is no filling back of the bridge wall. It is not desirable that the flame should "hug" the boiler. The effect of the relatively cold boiler shell is to retard combustion and what is desired beneath the boiler is the most complete combustion obtainable. The heating surface of the shell is but 11 per cent. of the total heating surface. It is in the tubes that the heat must be absorbed and not through the shell. Combustion must be complete before the gases enter the tubes. Complete combustion is furthered by a large combustion chamber, a low bridge wall and a considerable distance between the grates and the shell. Rather than contract these dimensions it would be preferable to increase them.

The side walls are made heavy not with the expectation that all cracks may be avoided but that the loss of heat from radiation may be reduced to a minimum. The air space in the walls to a limited extent, allows the inner wall to expand independently of the outer wall. But a certain amount of cracking of the outer wall is to be expected; if the cracks are kept pointed, so that no air is drawn in, no harm is done.

In place of putting a single course of brick over the shell the masonry is leveled off to the top of the side walls, making the top of the battery as smooth as a ball room floor. This floor can then be kept clean and free from the rubbish that is so prone to accumulate on the top of boilers. The fire hazard is materially reduced thereby. Furthermore, when the fireman has occasion to go there he does not fall over loose planks. Valves and manholes are accessible. In addition, this mass of brick work reduces heat losses. As a matter of fact it is never uncomfortably hot on boilers set in this manner. It is not advisable that a space should be left between this brick covering and the boiler. In fact such a space is decidedly objectionable, so the first course is laid immediately against the shell, thus effectually preventing the short circuiting of the gases with the consequent corrosion of the shell. The bottom of the ashpit is finished water-tight with cement below the level of the floor, and firemen are instructed to keep water therein. The evaporation serves to keep the grate bars cool. The use of live steam beneath the bars is considered as extremely wasteful and wholly unnecessary.

The boiler is set level. This is in direct opposition to the general practice of setting boilers high in front. The reason for settng level is that the flanges may come horizontal and taper joints be avoided. The only argument in favor of setting high in front is that scale and mud may drain to the rear. But the advocates of this practice only ask for an inch or an inch and a half in eighteen feet. It is not supposable that a slope of about one-sixteenth of an inch per foot, especially when the rear sheet makes a dam half an inch high at the center, can, to any appreciable extent, effect the currents of circulation along the shell. It is well known that the circulation establishes a current along the bottom of the boiler from the rear head forward. This frequently results in a deposit of mud and scale at the point where the heat is most intense, just forward of the bridge wall. That this current can be reversed and caused to flow in the opposite direction by so slight an inclination as one-sixteenth of an inch per foot is not reasonable. Owing to the expansion and contraction of the firebrick in the furnace there is a slight tendency for a boiler to settle in front. That the boiler may eventually rest level there is no objection to a slight elevation at the start; but the idea that a boiler should be set high in front that scale and mud shall wash to the rear is believed to be erroneous and not borne out by experience. Even if it were so, the area that is effected when the blow off is opened must be a very limited one. Only the mud in the immediate vicinity is removed. Blowing off is necessary that the blow off pipe be kept open and also that a change may be effected in the water, but it is not and cannot be a substitute for cleaning, however high the boiler be set in front. The way to prevent bagging is to keep the boiler clean and it is not believed that this end is in the least hindered by setting the boiler level.

There are no air passages in the bridge wall; no attempt is made to pre-heat air before combustion; there is no "secondary air supply" to the combustion chamber. These are purposely omitted, because, while they are very pretty points to talk about it is not believed that they are of any practical utility. The question of the use of automatic stokers, shaking grates, and patented furnaces, has received due and careful consideration, but despite the claims of sales agents and reports of tests, with all of which the engineering department is very familiar, that department remains to be convinced that any economy, at all commensurate with the cost, would be secured by their adoption. It would have been an easy matter to complicate this setting; the attempt has been made to simplify it. The drawing has been used to set about 150 boilers and no reason found for changing it.

THE FRONTS AND APPURTENANCES.

The fronts are of the full flush type and considerably heavier than those usually furnished by manufacturers. Door joints are not planed but castings must be smooth and true. Grate bars are of the type known as the Kelly bar. They present the largest possible proportion of air space to surface. Two blow off valves are provided; a 3″ asbestos packed plug cock and a 2½″ brass angle valve. It is occasionally necessary to renew the brass seat but between the two valves no trouble is experienced from leaking at the blow off. The feed connection is somewhat novel; upon the front four inch nozzle is mounted the casting shown on Plate III, Fig. 1. The two inch feed line enters the top of this casting; a two inch nipple is screwed in from the underside and connects by an ell to a two inch pipe that runs immediately over the tubes to within two feet of the rear head; a tee is placed on the end of this line that the feed water may be projected towards the side of the boiler and not against the back head. This casting is tapped at the side for a two inch pipe to supply steam to an auxiliary 4″ line that furnishes steam to the pump and injector. This feature of an auxiliary steam line, independent of the main steam header, is a valuable one in mining practice in that it permits of repairs to the header without cutting off the steam to the mine pumps. The steam line leading to the shaft, in addition to being connected to the header, is always connected to this auxiliary 4″ line. This arrangement of taking steam from the same connection that admits the feed water has been objected to on the grounds that the feed water has a tendency to cool the steam thus insuring a supply of wet steam to the pump. The condensing, or cooling effect of the few inches of pipe exposed cannot be but insignificant. Furthermore the steam to a feed pump is always throttled. The objection is not well taken. The arrangement is a most convenient one and the feed pipe is much more accessible than if it entered the front head after the usual custom. To tap a feed pipe into the shell is not considered good practice as the breaking off of pipes so placed is abundant testimony. The desirability of feeding at the blow off will not be discussed here. We are not open to conviction on that point. The combination of feed and auxiliary steam line from one nozzle has proved very satisfactory. Plate IV shows the arrangement in plan.

The auxiliary steam line supplies the feed pump and injector which discharge into opposite ends of a cast iron manifold, having as many openings as there are boilers in the battery. The feed is regulated at the manifold and not at the boiler; but, in addition to the feed valve at the manifold, a 2" angle valve, for emergency, is placed on each boiler and the check valve located adjacent to it. This check is made flanged on one end so that it cannot be set to open the wrong way.

The feed water heater is of the open type and the large majority of those in use are of the Webster make. The only objection that can be raised to the open heater is the danger of getting oil into the boilers. The oil separator must be cleaned and care taken that the heater does not become foul. In none of the cases of bagged boilers was there evidence that the trouble arose from oil. Troubles from leaking tubes and deterioration of closed heaters are considered more serious than the dangers due to oil incident to open heaters.

It is the practice of the company to heat the mine buildings by the vacuum system, using exhaust steam. This effects an enormous economy in fuel. At many of the mines the power can be considered as costing nothing, for the buildings, if heated in the usual manner, would require as much fuel as, with the vacuum system, serves to supply both heat and power. Or to put it another way, the heating costs nothing, and were it not for this use of the exhaust steam it would cost as much as the power. The use of the vacuum system calls for a back pressure valve that shall release at a maximum of two pounds and at the same time prevent the inleak of air when the flow line is under vacuum. There are on the market a number of back pressure valves which will, presumably, answer the purpose fairly well with engines having a constant exhaust. But a hoisting engine has not a constant exhaust. At the beginning of a trip it may exhaust at sixty pounds and after a few revolutions at atmosphere. Under such conditions a poppet valve can do nothing but pound; and it pounds itself to pieces. It became necessary to design a back pressure valve that will not pound. The result was the Wessinger valve, that rotates on its seat after the manner of a Corliss valve. It does not pound or leak and the many in use are giving entire satisfaction. By means of a reducing tee, adjacent to the heater, a connection is always provided for the vacuum system. To supply the system and also insure a high feed water temperature a considerable quantity of exhaust steam is demanded. In a few installations it has been deemed advisable to disregard engine economy, to a certain extent, that the volume of exhaust might be sufficient to supply these demands. This is cited as an illustration of what was before mentioned, namely, that the criteria by which a large central power station might properly be judged are not applicable to the boiler houses of this company. This is in no sense an apology; merely an explanation.

With the exception of high and low water alarm on the water column, provided to conform to the state law and not because it is considered an essential, and an automatic float valve controlling the supply of water to the heater, there are no automatic appliances in the boiler room. Automatic pump governors, damper regulators, boiler skimmers and such like mechanical devices, designed to do the work of the firemen and water tenders, are not used. For those who like those sort of things no doubt those are the sort of things they like. The question of the use of superheaters has received some consideration and may receive more. Where line condensation, as in the case of underground pumps, is considerable, there is little doubt that initial superheating would effect an economy. But in connection with hoisting engines, where the flow of steam is intermittent, resulting in great variations of temperature in the superheating apparatus, the use of superheaters is something of a doubtful proposition.

Careful attention is given to the matter of steam pipe covering. The only insulating material used is 85% plastic magnesia. It is applied two inches thick on all pipes up to seven inches in diameter and three inches on seven inch and over. This is expensive but the cost is materially reduced by having men at all the mines who can do a good job of covering. With this covering properly applied no hesitation is felt in running a steam line 1500 feet long, with expansion joints suitably located and pipes properly drained. It is an established rule, violated only in exceptional cases, that a steam line must pitch in the direction of flow. It is not conceivable that water can flow back along the bottom of a pipe against the velocity of the steam in the other direction. For this reason pipes pitch with the flow and to avoid water pockets it is the practice to use eccentric fittings where the diameter changes, that there may be no hindrance to the flow of condensation to the end of the line, where provision is made for trapping it off.

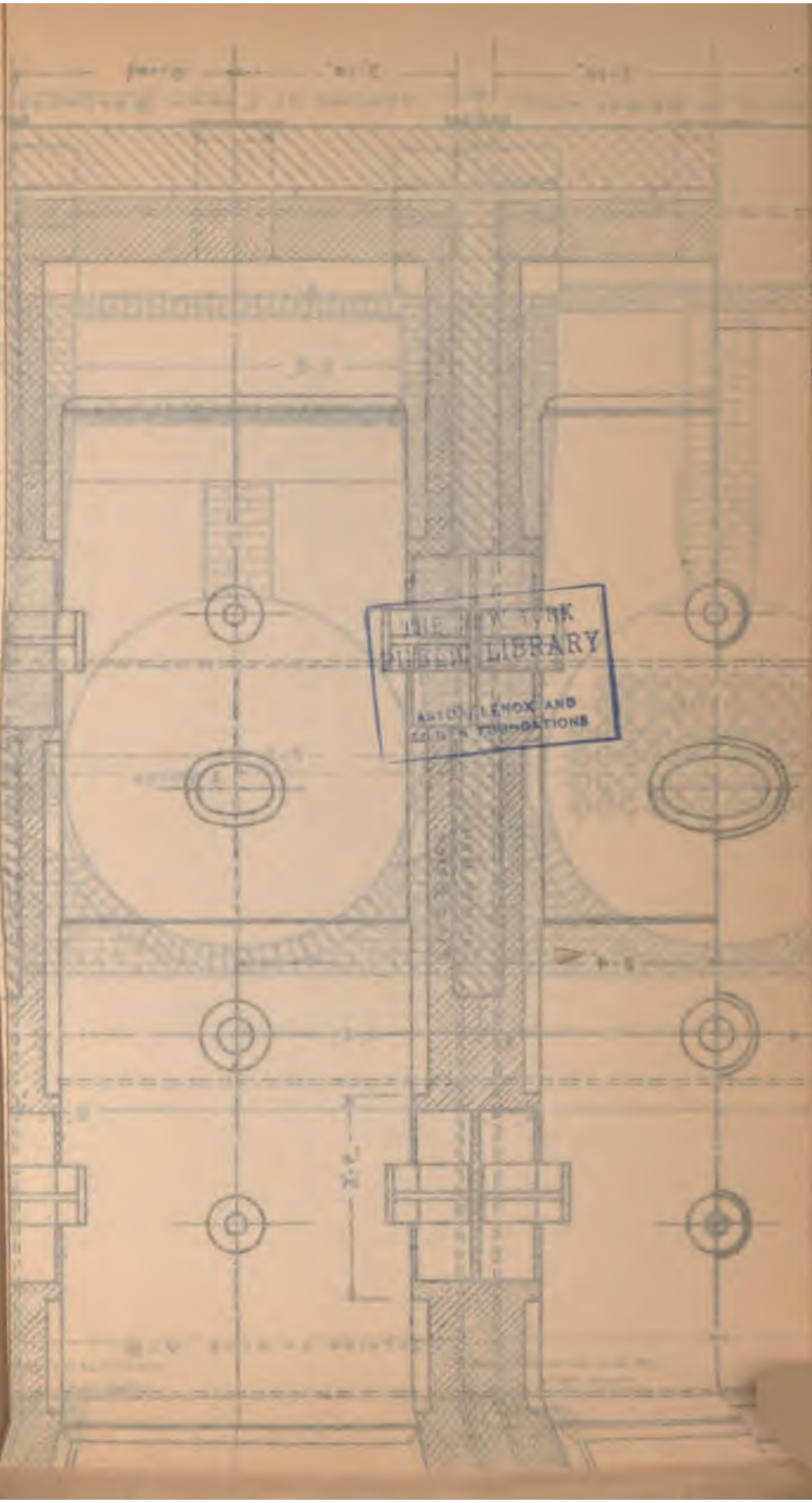
The size of the main header is determined by the number of boilers in battery but is always made larger than the total area of the pipes which it supplies. Thus it acts as a receiver and it is not the practice to use additional receivers on the lines. The header is connected to the boilers by curved pipes. Under no circumstances are stop valves placed next the boilers. They are invariably placed next the header. All valves, fittings and flanges, are extra heavy, cast iron, to the 1902 manufacturers' standard.

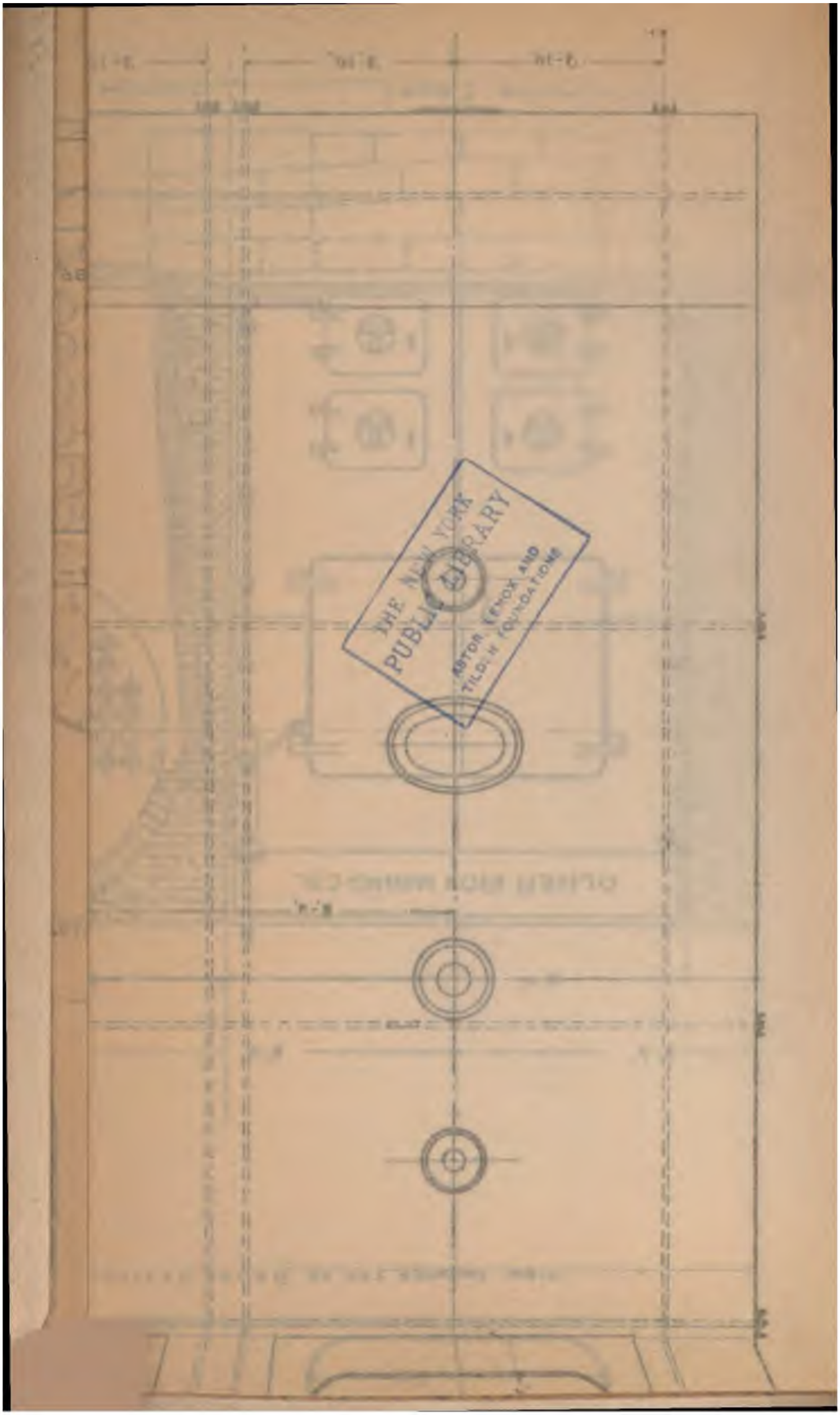
THE STACK AND BREECHING

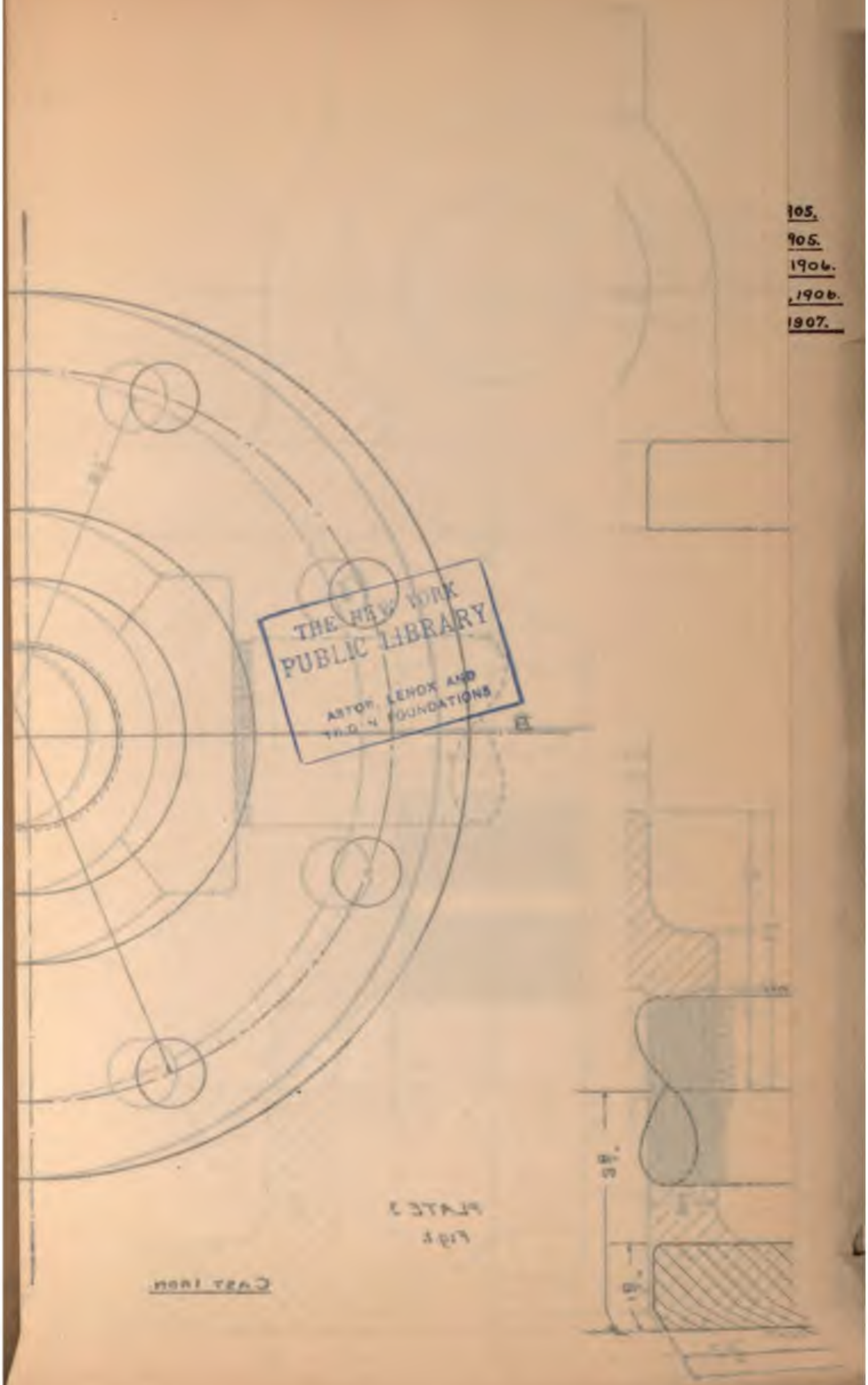
The breeching is made from No. 8 sheet steel. A damper is provided in the smoke connection from each boiler but no main damper is provided in the breeching proper. That portion of the breeching which is exposed to the weather, between the boiler house and the stack, is most likely to need renewal. Consequently this section is made so that it can be readily removed by connecting it to the remainder of the breeching by an angle iron flange located just inside the boiler room wall. Upon the question of stacks the practice has, in general, been to use brick, where a long life was anticipated, and steel where the location was on ore or where the plant was, to a degree, temporary. The permanency of the brick stack and the fact that it does not need painting, are considerations in its favor. On the other hand the first cost of a brick stack is more than that of a steel stack, made from light tank plate and guyed. But the life of such steel stacks has been in many cases surprisingly short, not over six years. The question of the desirability of the two types is now receiving careful attention from the Engineering Department. It is not impossible that some design of concrete stack may be adopted as standard, but as yet none have been built for this Company. The self-contained steel stack, brick lined, "blast furnace style" as it is sometimes called, has been considered in place of the brick. It requires as much foundation as the brick stack and must be kept painted. These brick stacks are contracted, erected in place, upon foundations, all labor and material being furnished by the contractor. In two cases these stacks have been struck by lightning but the damage was not material. Recent installations have been equipped with lightning rods. Plate III, Fig. 2, shows the stack in detail. Please note that there is no knob on the top. The primary purpose of a stack is to make draft. A knob does not assist the draft. That is why it is left off. Knobs are a matter of taste. No quarrel will be instituted with those whose tastes differ.

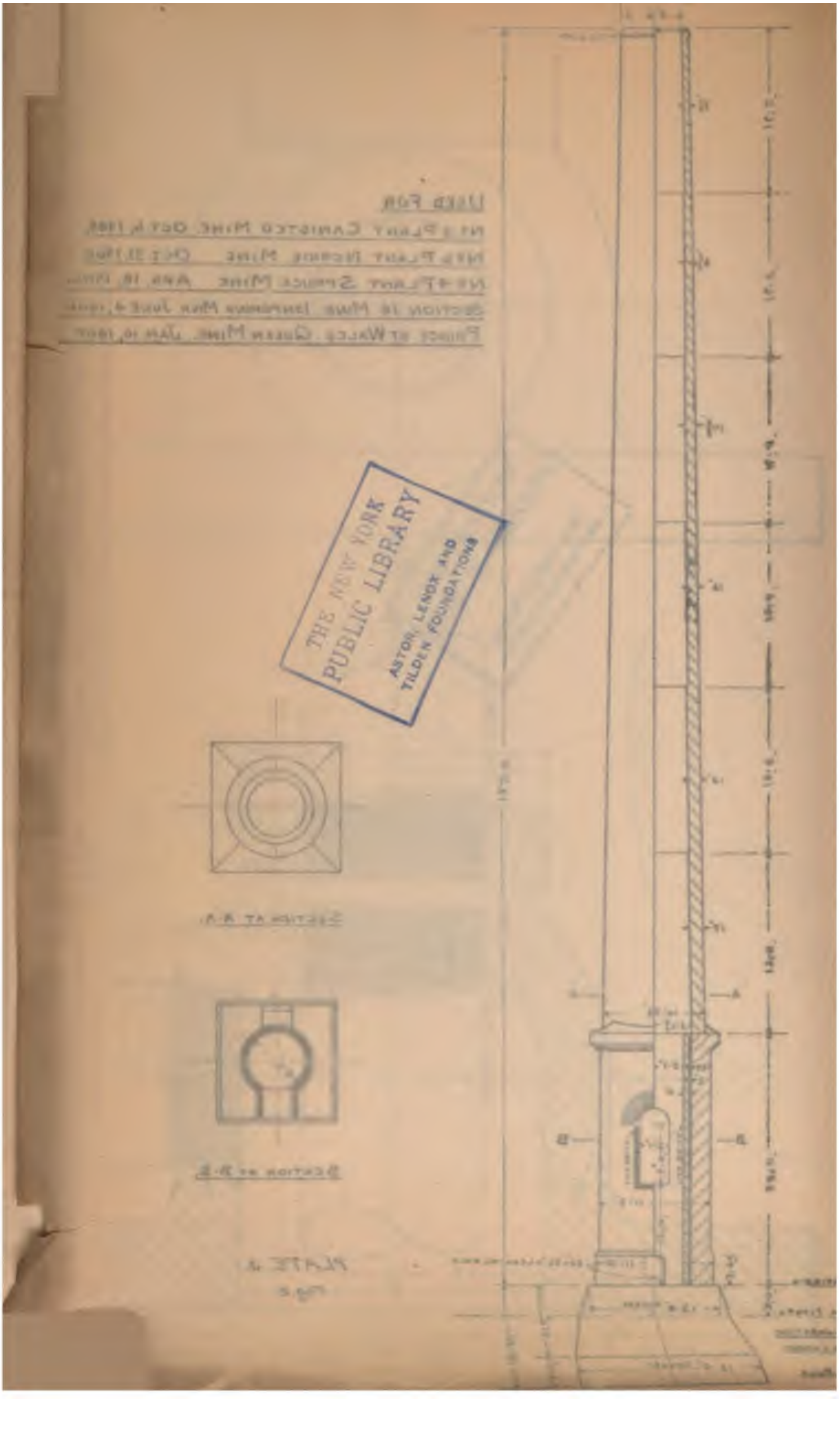
THE BUILDING.

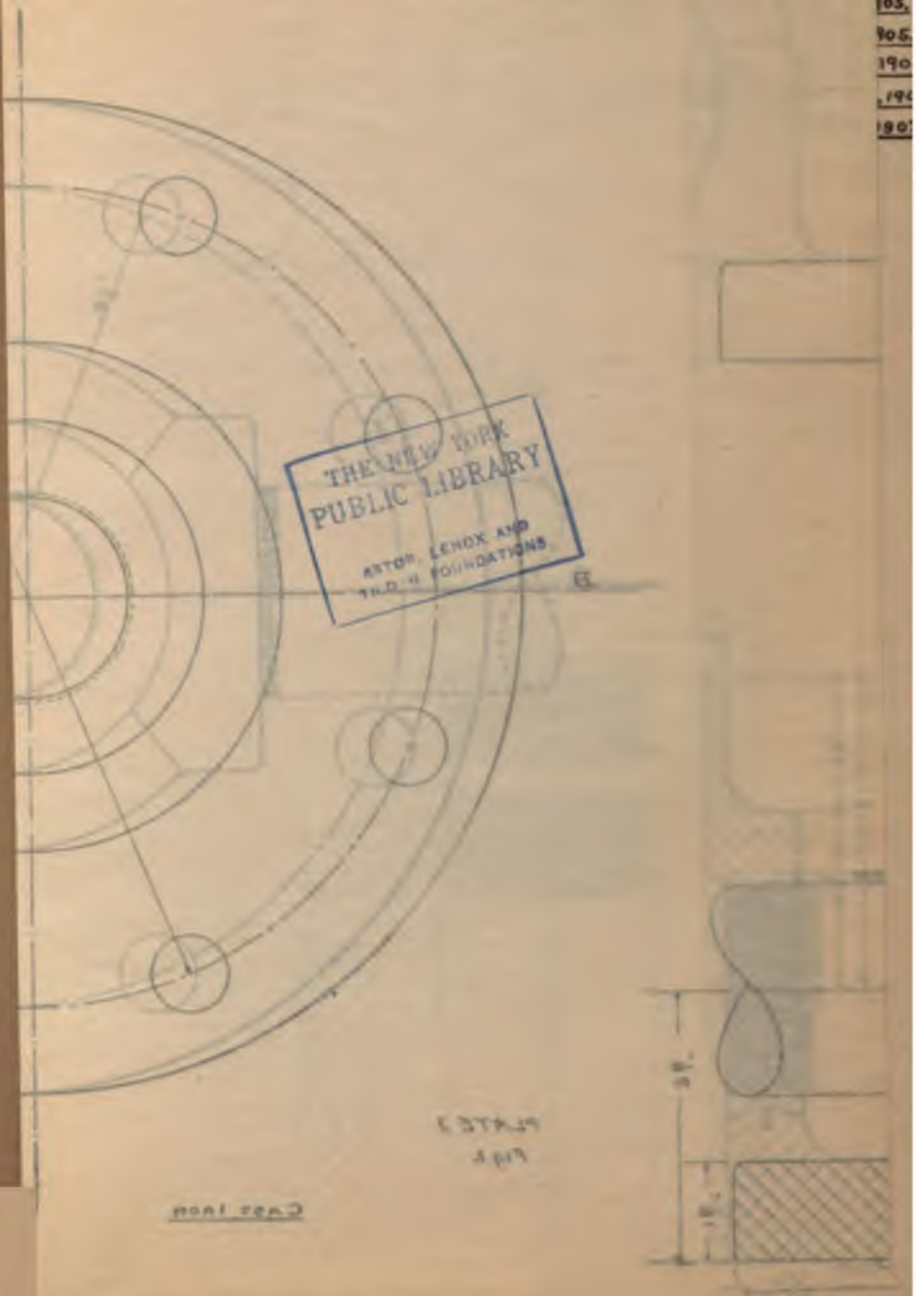
The building is shown on Plates V and VI. The standard construction consists of a frame skeleton covered with sheeting, building paper and corrugated, galvanized iron, and veneered inside with one course of brick, between the studding. This construction is followed on nearly all the mine structures such as engine houses, dry houses, small machine shops, warehouses and captain's offices. Because of the fact that, winter or summer, buildings of this type may be erected by labor available at the mines and from material always readily obtainable, the construction has proved itself eminently adapted to the requirements. The wooden superstructure can always be framed and erected by the mine carpenters and then the work inside may be proceeded with regardless of the











weather, and the corrugated iron and brick veneer put on when most convenient. The brick veneer materially reduces the fire hazard, makes the building much warmer and presents a neat and finished appearance. The brick are laid flush with the studding, so that the wall is smooth. Sheeting is laid diagonally, covered with building paper and finished with corrugated iron. The same weight of corrugated iron is used on roof and sides. It is customary to use heavier iron on the roof than the sides on most buildings but it was found that when the bundles of iron were opened the sheets were almost certain to get mixed. This is merely cited as one of the many small details that have been considered. As to the relative merits of galvanized and painted iron there is a difference of opinion among engineers. The experience of the Oliver Iron Mining Co. favors the use of the galvanized sheets and as yet the pitting of the sheets has not rendered painting necessary.

Plate VIII shows the design of the wooden roof truss. The wooden roof truss in a boiler house has been objected to on account of the fire risk. The members of this truss are heavy and the bottom chord is always placed well above the breeching. To reduce the fire hazard to a minimum the truss is kept well whitewashed. Steel construction has been considered for such buildings and may, later, supplant the wooden standards followed up to this time. Considerations of first cost and convenience in the matter of erection, from the standpoint of both labor and material, led to its adoption. With the constantly increasing cost of timber and the constantly increasing facilities for obtaining and erecting steel structures it is possible that the design may be changed to steel construction. Plans and estimates have already been made on certain buildings that comparison may be instituted between the two types of construction. For all large buildings steel construction is used. In fact, the use of steel is constantly increasing in the mining business. Steel tram cars are taking the place of wooden ones Steel head frames are being used more and more and on deep, permanent shafts steel shaft sets and stuttles are in many cases substituted for wood. But for small mine buildings, where the necessity of following some standard practice is urgent, this brick veneered construction has proved itself to be very desirable.

The roof of the boiler house is always hipped parallel to the battery that extensions may be made if desired. For ventilation a monitor with wooden louvres is provided and upon recent installations wire screen is put over the openings for the industrious sparrow finds the top of a warm boiler house a suitable place for nest building, using all the inflammable rubbish in the neighborhood.

The best way to get the coal within easy reach of the firemen is something of a problem. Overhead bins, filled by elevators and discharged by spouts, while admirable for large plants, present cost considerations out of the question in plants the size of these. At the same time coal storage for the winter months is absolutely necessary. The plan as adopted and in use on all new plants is shown on Plate VII. A coal trestle is erected alongside of the boiler house and in this connection it is well to remark the site of the boiler house is usually considered in connection with the possibility of getting a trestle to it at proper grade. Upon the side of the boiler house are built bins that discharge coal within reach of the fireman's shovel. In summer time, when coal is being regularly received in drop bottom cars, the bins are kept full directly from the cars. The winter supply is stored between the bents of the trestle. At one end of the boiler house is a coal elevator, simply a platform raised and lowered by means of a steam cylinder within the boiler house. A coal buggy having been filled is run on the elevator, raised to the level of the bins, run into the house and emptied directly into the same bins that in summer receive their coal direct from the cars. There is no wheeling in of coal and dumping it on the floor. Having filled the bins the laborers are available for work elsewhere until the bins need to be filled again. The records of cost show a notable saving per ton by this method of coal handling.

At the back of the boilers is provided a trench, covered with cast iron plates, to receive the blow off pipe and exhaust pipes leading to the heater. It is considered very bad practice to locate the blow off pipe underground, or where it is not accessible. Furthermore the end of it should be visible. Steam and water coming from this pipe is the surest indication of leaking blow off valves.

Where the battery consists of but two or three boilers the engine room is, usually, built as part of the same building that houses the boilers, the two being separated by a brick partition wall. On larger plans the engine house is a separate building, of the same general construction that has been described.

COSTS.

A boiler plant, built to these designs, containing four boilers, brick stack, coal hoist, and everything complete, ready to raise steam, costs about $20,000.00. This does not include the coal trestle. From the estimates and actual costs on several installations the following cost sheet is made. It is assumed that the location is such that convenient delivery of material can be made by rail; both labor and material are higher than they were a few years ago, when the same installation could have been made for $19,000.00.

Excavations	$ 250.00
Foundations	2,200.00
Building	3,200.00
Boilers, grates, fittings	4,700.00
Setting, complete	3,000.00
Chimney	3,200.00
Pump, injector, heater	1,000.00
Piping and valves	1,800.00
Pipe covering	350.00
Coal hoist and car	700.00
Total	$20,400.00
Water tank, erected	700.00
	$21,100.00

An examination of many boiler houses might lead an observer to the conclusion that a boiler house was of necessity a dark, dirty, hot place, a sort of an inferno, where life for the fireman was a foretaste of the orthodox future. It is to be hoped that in going over the Mesabi range you will not receive this impression from an inspection of the boiler houses of the Oliver Iron Mining Co.

THE SAMPLING OF IRON ORES.

By L. S. Austin, Houghton, Mich.

Since iron ores are purchased according to their grade, that is according to their contents in iron, silica and phosphorus, it is necessary, in order to determine that grade, to obtain a sample representing the exact average of the lot or cargo which is to be purchased. This, accompanied by its gross weight and its percentage of contained moisture, enables us to determine its value. Since the grade of the ore depends upon the analysis of the dried sample, the percentage of moisture gives us the actual dry weight from which is estimated the net returns on the cargo, shipment or lot.

The literature on the subject of sampling is extensive and easily accessible,* and the subject has been thoroughly developed upon its theoretical or mathematical side. It would seem necessary in sampling the ores of iron, to consider simply the application of these principles to a mineral easy to accurately sample, and, the substitution in the general formulae of the known variations, would give the approximation to perfection which we would have a right to expect.

It would be an exaggeration to say, as I have heard it said, that the older way of cargo sampling consisted in taking portions at the will of the sampling men, who would take them as they felt like it, and between the periods of rest needed to smoke a comfortable pipeful of tobacco. Were such a method

*Reed, School of Mines Quarterly III, p. 253, VI 351.
Brunton, Trans. A. I. M. E., XIII, p. 639.
Hofman, Metallurgy of Lead.
Peters, Modern Copper Smelting.
Richards, Ore Dressing.

followed it might even then chance to come out exactly, or in a correct average for that period. Still, why go even to that expense, and why not take a handful from each cargo under the idea that the true amount would be arrived at in accordance with the doctrine of averages. If the ore were in all parts of uniform grade, such a way might be good enough, but, since iron ores can greatly vary, especially in phosphorus, such a method of taking might easily be wide of the truth.

In a paper, contributed to our proceedings four years ago by Mr. Separk,* and in a more recent one brought out by W. J. Rattle & Son** on cargo-sampling at lower lake ports, one is struck by the fact that the methods then used were defective in principle, since they did not represent the entire body of ore uniformly, and since, especially under the conditions which Mr. Separk described, the mixing of the ore from which the sample was taken was imperfect. So far as mixing is concerned I will note the experience in the copper country in the sampling of their mineral. Here the South Range copper mines send their mineral, while in an imperfectly mixed condition to the Michigan Smelting Works, which, in their earlier experience, had trouble in getting duplicate samples to agree. Later, the method of receiving the material was modified by dropping the contents of the hopper-bottom railroad cars into a receiving hopper, this into a smaller hopper-bottom transfer car, and finally from this into the storage bin at which point the sample was taken. The railroad car was also loaded at the mill from a receiving hopper. Thus the mineral was mixed four times before the sample was taken, and this overcame the difficulty.

One may infer from this, that by the time the ore is sampled at lower-lake ports the mixing has been well performed, and so true is this that the methods of W. J. Rattle & Son, imperfect in principle as they then were, still gave results

*Volume X, pages 103-126.

**Volume XI, pages 173-180.

which were not called in question.* In that method so much of the ore had been removed as to leave what might be supposed to represent it on each side or face of the cavity. As the ore is shot into the hold it piles up, forming concentric layers, the lumps rolling to the exterior, and it is this portion that was not properly represented. We come finally to the conclusion, that if iron ore is to be sampled at all, it must be correctly sampled, and until we come to this there will always be uncertainty and dissatisfaction, both on the side of the buyer and of the seller. As Mr. Separk brought out the matter in his paper read before the Institute in 1904; "Sampling is the most important feature of this work."

When at Escanaba three years ago, the Institute witnessed the method of crushing the hard ore of the range through a large gyratory crusher, the product being delivered by a troughed conveying-belt to a receiving pocket and thence to cars which transfer it to the ore-docks, that is, it is crushed in transit.

Now let us suppose we desired to sample the ore: It would be at the point where it was about to be delivered to the receiving hopper, and where the ore has been spread out uniformly on the troughed belt, that it would be possible to take a sample so as not to interfere with the ore-handling and yet give a regular and reliable sample. To do this it would be easy to cut out by an automatic sampler, one-tenth of the ore-stream at the discharge end of the belt, the nine-tenths entering the receiving pocket. The sample would now be fed by a feeding shoe to another crusher, being there crushed and mixed, and then to a second sampler, which again takes out one-tenth; the rejected portion being at once returned to the receiving hopper. The running sample thus taken, in no way interrupts the delivery of the ore and its shipment as fast as crushed. The sample could now be treated in one of two ways: It may be allowed to fall upon the sampling floor in a heap (which mixes

*For the more recent method of sampling see Mr. Oscar Texor's description at the conclusion of this paper.

it) and may be put through crushing rolls, then through another sampler taking out one-tenth. This would give us, to complete according to any of the finishing methods, but one ton of sample from 1,000 of ore. Otherwise the ore, coming from the second sampler, may be sent over a feeding-shoe to rolls and then to a third automatic sampler. In either case this portion, a thousandth part of the whole is completed by the ordinary finishing methods.

One would say, that while such a system of automatic sampling as above described, would be applicable to hard ore where the ore is to be crushed, it would hardly do for soft ores which need no crushing, and where one would wish to avoid the additional expense of so handling. On the other hand I do not doubt that such a plant, if carefully designed, could take care of the ore at but little additional expense per ton of ore handled, and above all both shipper and buyer could be sure of the precision of sampling, and the chances of uncertainty and disputes would be lessened.

Of sampling methods, coning and quartering, as commonly practiced, is defective. In this the ore is wheeled to and dumped in a ring upon the floor within which it is afterwards coned up. This ensures a mixing, but at the same time a segregation occurs owing to the coarser material (which may be of lower grade) finding its way to the perimeter of the forming cone. If it were possible to keep the apex of the cone truly vertical, and to spread it out symetrically from the center when completed, the opposite quarters would be truly representative of the whole, but, since this spreading or distribution is irregular, so is the consequent sample. A more accurate way is to reserve every fourth shovelful of the sample when shoveling it. This smaller amount, again crushed finer, can be worked down by means of a riffle until its quantity is so small that it may be finished upon the grinding plate.

The requirements for correct sampling ore

(1) Frequent taking.
(2) Progressive crushing.
(3) Proper mixing.

These conditions are fulfilled in the automatic sampling just described. It will be noticed that throughout the process all parts of the ore are equally represented; that the proper proportionate amounts of coarse and fine ore are taken; that the ore is sampled independently of the judgment or discretion of the men who do the sampling, and by which the personal equation is eliminated; and that it is done without interrupting the movement of the ore as it comes in. If experience should show that a smaller aliquot portion of the ore can be taken, the automatic sampling can be modified to suit the new conditions.

I would recommend that at first the sampling should be done in duplicate until the requirements for its exact performance are known. This having been accomplished, the duplicated samplng can be omitted. This policy was pursued at one of our Western ore-treatment mills, where the ore was quite uneven or spotty, and where nevertheless the duplicate samples had to agree closely with one another.

In theory the moisture sample is to be taken at the instant of weighing and we are generally satisfied to take out a portion from time to time for a moisture determination as the weighing proceeds. Several of these determinations combined give a fair average value of the moisture present. This sample is, however, less important than the one from which the chemical determinations are made. For all that, less attention is given to moisture determinations than should be. A result in moisture reported several tenths of a per cent. too high, makes just that much to be deducted from the returns on a cargo.

This brings one to the more radical idea, that is to one which would affect the arrangement and construction of ore docks and the handling of ore at them. Take for example the case of ore docks costing $600,000, and whose life even with constant repair would be some 12 years. The alternative, which I have known a certain engineering firm to propose, was to put in a more permanent structure involving the storage of the ore in stock-piles, and the reclaiming of it for delivery to comparatively light but permanent shipping pockets, the installation to cost but half as much, for the same capacity, as the present docks. Under such a system where the ore is being rehandled to go to the pockets it may be automatically sampled as already specified. While to me this method seems feasibe, it is quite possible that it has been, so far as the storage method is concerned, gone over and rejected. The general methods involved are not in themselves new, and they have elsewhere been put in practice. Whether they would do well on the large scale here demanded is a question. There is a natural conservatism and the desire of working along well-tried lines, which is against a radical change. Still one of the large companies could begin in a tentative way after the study of existing methods already worked out, and with the aid of those who have solved the problem under different conditions.*

The engineer engaged in construction keeps busy at his works and has (or thinks he has) but little time to leave it to observe methods elsewhere. He should make the effort and take the time to see what is being done. The yearly trips of the Institute illustrate the benefit of so doing.

*I would note among reclaiming plants
The Garfield plant of the American Securities Co. at Garfield, Utah.
The Greene-Cananea plant at Cananea, Sonora, Mexico.
The South Chicago plant of the Illinois Steel Co.
Stocking and reclaiming systems of the Semet-Solay Co. at Milwaukee and South Chicago.

(Through the kindness of Mr. Oscar Textor, of Cleveland, Ohio, the secretary is enabled to add to this paper a brief description of the standard methods for sampling cargoes of iron ore at lower lake ports as adopted by the independent chemists for the season of 1907. This is published herewith in order to give the members all the information possible in preparing for discussion on this subject).

STANDARD METHOD FOR SAMPLING CARGOES OF IRON ORE AT LOWER LAKE PORTS, 1907.

A continuous sample shall be taken from all cargoes, thus insuring a large mechanical sample, the weight of the sample varying with the size of the cargo.

The samplers shall begin sampling as soon as the vessel begins unloading, and shall continue sampling until the cargo is unloaded. The sampling of each hatch shall be begun shortly after its unloading has begun, and the ore in each hatch shall be sampled as the unloading progresses at such intervals of time as to correspond with at least four distinct stages of unloading, and the ore shall be sampled at regular measured intervals over the surface exposed so as to represent practically all the ore in each hatch. The sampling shall be done in the hold of the vessel, except at times when conditions make sampling in the hold dangerous and unsatisfactory, in which case no more than one-fourth (¼) of the total sample may be taken from the cars. No sampling shall be made from the original outside surfaces of the ore nor from the stock-pile.

Beginning at a convenient point, one full scoop of ore shall be taken in a standard trowel at each point sampled, and these points shall be at regular measured intervals, which shall be of a length eventually to be determined by our experience in the early part of the season. When a lump is encountered at the point from which the scoop of ore should be taken, a portion shall be broken off equal in amount to the fine ore taken in the scoop. As in sampling hard lump ores a scoop cannot be used, small pieces must be broken off with a hammer. Although the number of points sampled will remain the same, the amount taken at each place sampled will be so much less that the total amount taken from the cargo as a sample will be necessarily smaller than in the case of soft ores.

This method of sampling shall be continued at regular intervals of time during the process of unloading, i. e., the samplers shall work continuously. The sample must be carefully protected during the sampling and must not be quartered until the sample is complete, but it may be prepared for quartering by breaking up the lumps. The sample may be quartered down on the vessel or may be taken to some other suitable place for that purpose. Samples must be shipped to the crushing plant in standard cans.

In sampling cars, the sampler shall sample from one end of the car to the other, taking full scoops of ore at regular intervals not less than one yard apart as described above.

The moisture sample shall be a separate sample and shall be taken when the vessel is half unloaded. It shall be taken on lines midway between the side and center of the boat on both sides of the center line of the vessel by the same spacing method. This sample must be taken wholly from fresh surfaces of ore that have not been exposed to sun or rain. It must be thoroughly mixed at once after it is taken, quartered down, and twenty pounds placed in a standard moisture can with tightly fitting cover and shipped without delay, or the moisture may be determined at the port where sampled, where proper facilities are provided. Every hatch must be represented in the moisture sample. The total moisture sample shall be weighed accurately, dried at 212° F., till the weight is constant, weighed again, the loss in weight representing the moisture in the cargo on arrival.

The above directions must be adhered to, day and night during the unloading of each cargo.

The following references are given to previous papers which have been presented to the Institute and to which reference may be made in the preparation of discussion:

Subject.	Vol.	Page.
Distribution of Phosphorus and System of Sampling at the Pewabic Mine, Michigan, by E. F. Brown, 1895...	III	49
Methods of Sampling Iron Ore, by C. T. Mixer, 1896....	IV	27
Some Aspects of the Analyzing and Grading of Iron Ores of the Gogebic Range, by Edward A. Separk, 1904..	X	103-126
Methods of Iron Ore Analysis Used in the Laboratories of the Iron Mining Companies of The Lake Superior Mining Region, by W. A. Siebenthal, 1905..........	XI	71-138
Cargo Sampling of Iron Ores at Lower Lake Ports—Including The Methods Used in the Analysis of the Same, by W. J. Rattle & Son, 1905................	XI	173-180

BIOGRAPHICAL NOTICES.

The following paragraphs comprise such information as your biographical committee has been able to obtain concerning the lives of prominent men, now deceased, who have taken an active part in the development of the Lake Superior country. The data here given has been secured from sources which we consider reliable.

J. H. HEARDING,
W. J. OLCOTT,
GEO. A. NEWETT,
J. B. COOPER,
Biographical Committee.

JOHN HARRIS FOSTER.

Born at Erie, Pa., May 29th, 1822. Studied engineering, and went to work as civil engineer in 1844. Came to Lake Superior region in 1846, and left there in 1849, to go as assistant engineer on survey of Mexican boundary. After finishing this work he went to Alta, California, remaining there until 1855, when he returned to Detroit, and entered employ of United States government on survey of great lakes. Was married in 1855 to Martha Mullitt. In the fall of 1860, he was appointed superintendent of Pewabic and Franklin mines in Houghton county, and managed these institutions for five years. In 1864-5, was chosen to represent the upper peninsula in state senate. In 1874, on account of poor health and a crippled leg, he returned to his farm near Lansing, Mich., where he remained until his death, June 15th, 1894. He was a memger of the Michigan Pioneer society and contributed a number of papers to its publication.

SILAS W. GOODALE.

Born in 1844 at Olean, N. Y. Entered army during latter part of civil war and was wounded. Was admitted to bar at Detroit about 1868. Practiced law first at Detroit, and then at Saginaw, Mich. Later he became court reporter, and was occupied as such for 32 years on the upper peninsula. He died May 4th, 1908, at Houghton, Mich. Though not connected with the mining industry, he was widely known and highly esteemed by the mining men of the upper peninsula.

WILLIAM H. HEARDING.

Born in 1827 at Adderbury, England. Came to United States in 1847, settling at Pontiac, Mich. On survey of great lakes from 1857 to 1864. Went to northern peninsula of Michigan in 1864, and acted as engineer for Quincy, Franklin, Pewabic, and South Pewabic, (near Atlantic) mines. Returned to the employ of United States government in 1867, and remained on harbor improvement work until his death in 1893. Mr. Hearding was engineer for Edwin Hulbert in locating surface outcrop of Calumet & Hecla mine.

GEORGE HAYDEN.

Born in Charlotte, Eaton Co., Michigan, October 23rd, 1850, was educated in this state and graduated from the law department of the Michigan university in 1871. In 1873 he came to Ishpeming where he resided until his death, during this time building up a lucrative practice in his profession, representing some of the largest interests in the district and taking prominence in educational and other public institutions. It was largely due to his efforts that the Lake Superior & Ishpeming railway was built and at the time of his death he was president of the Fort Smith and Western railway, a line running westward from Fort Smith in Indian Territory. Mr. Hayden at the time of his death was a member of the board of school trustees of Ishpeming, a position in which he was of great help to the schools and where he worked faithfully to improve the tone of Ishpeming's educational interests. He served Marquette county as its prosecuting attorney in 1885-6, making a record for good service which is still well remembered by the people. He was also city attorney of Ishpeming for several years. He was a 32nd degree Mason and a member of the local Blue lodge, the Commandery and Mystic Shrine of Marquette, and the Consistory of Grand Rapids. Mr. Hayden's death occurred in Chicago on Wednesday, July 23rd, 1902, where he had gone to undergo an operation for some internal trouble. He was of a happy disposition, fond of out-of-door sports, took great delight in accompanying his children on long walks over the hills and sharing the pleasures of the camp fire with his family and friends.

DOUGLAS HOUGHTON.

Born in Troy, N. Y., Sept. 21st, 1809. Graduated from Van Rensselar school, N. Y., 1828. Soon appointed professor of chemistry and natural history in the same school. In 1830 he was appointed by General Cass and Major Whiting of Detroit to lecture on chemistry and geology in Detroit, thus bringing him to Michigan. Appointed surgeon and botanist for Schoolcraft's expedition to source of Mississippi in 1830, by secretary of war. During the next 15 years was elected mayor of Detroit twice and was offered the presidency of Michigan university before he was 30 years old. Appointed state geologist in 1837. As such he made many discoveries concerning the mineral bearing formations of the upper peninsula and especially those of the copper bearing series. On such an expedition he lost his life while attempting to get to Eagle river in an open boat on Oct. 13, 1845. His distinction lies in being the first scientific investigator of geological conditions in the upper peninsula.

WALTER M. JEFFERY.

Born in Humboldt, Michigan, April 12th, 1871. When 2 years old the family moved to Negaunee, Michigan, In June, 1889, he graduated from the Negaunee high school. In the fall of 1889 he started to work in the office of the Queen mines, under Mr. Cole's management, mines being owned by Schlessinger. In 1891 the mines were purchased by Corrigan, McKinney & Company. He was with them until the spring of 1894, when upon Mr. Cole's advice, he went to Hibbing to take a position at the Mahoning mine with Mr. Agnew, staying there until September, 1894, when Corrigan, McKinney & Co. again wanted him to enter their service in the home office at Cleveland, which he did in the fall of 1894, staying with them until December, 1897, when he again acted on Mr. Cole's advice and went to Milwaukee for the Oliver Iron Mining company. He remained in the Milwaukee office as chief clerk until December, 1899, when he went to Pittsburgh as assistant auditor for the Oliver people. In June, 1900, he was made auditor of this company. Died in May, 1906.

SAMUEL MITCHELL.

Born in Devonshire, England, in 1844. Came to America in 1862 and began working at the Phœnix copper mine and later with the Madison Copper company. After which he worked successively with the Calumet & Hecla, the Cliff, the Saginaw, and many other mines both iron and copper, advancing gradually to positions of importance. He sank the first sand shaft in the Lake Superior district at the Negaunee mine, which property was operated under his personal supervision several years. During the years intervening between 1886 and 1890, he was chief factor in the development of the Montreal River Iron Mining Co., on the Gogebic range, and in 1887 he also became largely interested in the Jackson Iron Mining Co., becoming its president and general manager. He was interested in a number of banking institutions, including the First National of Negaunee, the Miners of Ishpeming, and at various times was interested in the First National of Marquette, First National of Hurley, First National of Escanaba, and Lincoln National of Chicago. He was also interested in some of the mining ventures on the Vermilion range. He died in Chicago, May 12th, 1908.

DONALD M'VICHIE.

Born in 1847 at Lanchester, Glengarry Co., Ontario, Canada, where he passed his boyhood days, coming to the upper peninsula of Michigan when 21 years of age and settling at Munising where he secured employment in the old Munising furnace, then in operation. In 1871 he came to Ishpeming, securing employment at the old New England mine under S. S. Curry, who had charge of the property at the time, remaining in Ishpeming for a couple of years. In the early days Mr. McVichie gave some attention to politics, holding several offices of trust. In 1878 he was chosen marshal of the city, filling the position most efficiently for six years. Upon the election of Grover Cleveland to the presidency for his first term, he appointed Mr. McVichie revenue collector for this district. During Cleveland's second administration, he was made postmaster, holding the office for four years. Mr. McVichie was a staunch gold democrat, one who firmly believed in the principles of his party and would listen to none of the isms of the later day illusionists. Besides being the active head of the Marquette County Telephone company and the Anthony Powder company, he was also vice-president of the Miners National bank and also held a seat on the directorate of the institution. Mr. McVichie was also a 32nd degree Mason. He was taken ill in the fall of 1905 with dropsy of the heart in a mild form but his condition gradually grew worse until his death September 14th, 1906. He was a true friend, a fair fighter and a man in the strictest sense of the term.

HARLOW OLCOTT.

Born in Hunts Hollow, N. Y., December 2nd, 1821. Educated in Nunda Valley college, N. Y. In 1842 he came to Salena, Mich., and studied medicine for two years. In 1843 he married Elizabeth Fifield, From 1844 to 1867 was principal of schools in Salena and Detroit, Mich. In 1867 he came to Marquette, Mich., as superintendent of schools, remaining until 1877 when he took a similar position at Ishpeming, Mich., resigning from that place in 1894. He then removed to Ann Arbor, Mich., where he died in April, 1901. Though not connected directly with the mining industry, his influence as an educator extended throughout the entire upper peninsula, where he was very widely known and greatly respected.

AMOS SHEPHARD.

Born at Linden, Wis., May 5, 1861. During his childhood he had limited advantages, working during the summers hauling lead and zinc ore from Linden to Mineral Point, from where it was shipped. He worked in this way until 1878, when he applied and received a teachers' certificate, W. A. Jones, who afterwards was commissioner of Indian affairs was county superintendent at the time. He again entered school, going to the State Normal at Plattville for ten months, which ended his educational advantages. On his return home he again labored in the mines at Linden, until the fall of 1879, when he taught school in a district near Linden. In the spring of 1880, he went to Quinnesec, Mich., and secured employment in the mine at that point as a miner. Being a good penman, he was soon made timekeeper by Capt. N. Cowling. By hard and efficient work, he arose from timekeeper to head accountant at the Quinnesec mine, where he remained until 1884, when he moved to Tower, Minn., taking the position of head accountant for the Minnesota Iron Co., under Capt. E. Morcome, superintendent. This position he held until January, 1889, when he was elected register of deeds, St. Louis Co., and moved to Duluth. He continued in office for six years, at the end of which time, he refused re-election and accepted the position of under sheriff for two years. During the years 1897-8, he traveled extensively in old Mexico and the western states. He was then appointed, by Jos. Sellwood, superintendent of the Cuff mine at Iron Mountain, Mich. He remained there for about two years and was then transferred by Mr. Sellwood as superintendent of the Atlantic mine at Iron Belt, Wis. About January, 1902, he entered the employment of Corrigan, McKinney & Co., with headquarters at Hibbing, Minn. Subsequently the old range mines of that company were put under his charge. He remained in this position until his death, June 6th, 1905. His jovial disposition, keen sense of humor, and fund of anecdote made him one of the most popular members of the Mining Institute.

JOHN STANTON.

Born in Bristol, England, February 25th, 1830, came to Pennsylvania in 1835. Studied engineering and managed his father's iron mines at Dover, N. J., up to 1852, when he became interested in copper mining in Tennessee, Maryland and Virginia. In 1861 he turned his attention to the richer Lake Superior mines and particularly the Atlantic mine, then the South Pewabic, which he developed to a paying mine though the ore was considered very low grade. He was connected with several mines opened at a later date and especially with the exploration of the newer and successful South Range mines. At his death he was president of the Baltic, Michigan, Mohawk, Winona and Wolverine companies and director of the Atlantic and Copper Range Consolidated companies and the Michigan Smelting company, and was interested in some properties in Arizona and British Columbia. He was one of the founders of the old New York Mining Exchange in 1876. Executive officer and statistician of Copper Producers association about 1890, remaining as such until its abandonment, also connected with the Trimountain Mining Co. He died in New York, February 23rd, 1906. Mr. Stanton was greatly admired and respected by all his associates as being an honest, conscientious and able man.

WILLIAM THOMAS.

Born in Cornwall, England, April, 1858. He came to

America and settled at Negaunee, Michigan. Moved to Ironwood, Mich., in 1886. Was a miner, shift boss, and night captain, in succession at the East Norrie mine. Later he was appointed captain of the Aurora mine, and while acting in such capacity he was shot and killed by an Italian whom he had refused work, Jan. 6th, 1908.

JAMES H. TREBILCOCK.

Born on the 21st of May, 1848, at the village of Ashton, parish of Breage, in the county of Cornwall, England. He was the third son of Mr. and Mrs. William Trebilcock. He came to Ishpeming direct from his native country in the summer of 1868 and resided at Ishpeming continuously until his death. In 1880 he was appointed mining captain of the Lowthian mine, one of the properties owned by the Lake Superior Iron company. Later he took charge of the Lake Superior Hematite and Section 16 mines as mining captain and held that position for about 20 years until a short time before his death. He was one of the best informed men on mining matters in the upper peninsula and was a most conscientious and careful mining captain in the care of those in his employ. In politics Captain Trebilcock had always been a faithful republican and took a deep interest and part in local and national affairs. He served the city of Ishpeming as supervisor, alderman, member of board of education, and mayor, filling these offices with conscientiousness. He was an active member of the Knights of the Golden Eagle, the Sons of St. George, and of the Independent Order of Odd Fellows and of the Lake Superior Mining Institute. He died October 19th, 1901.

WILLIAM TREBILCOCK.

Born on April 24th, 1845, at village of Ashton, parish of Breage, Cornwall, England, and died October 15th, 1905, at Falmouth, England. He commenced working in the mines of his native place at a very early age and continued to do so until the spring of 1866. In April of the year 1866 he decided to go to the United States and in the early part of May left his native land and went direct to the copper country where he found employment at the Cliff mine, remaining there for about a year; he then came to Ishpeming and worked at the Cleveland mine for about three years; leaving Ishpeming he went to the mines of New Jersey, later going West to the mines of Idaho and Oregon; after an absence of a year or two he returned to Ishpeming and was employed at the Lake Superior mine where he did considerable contract work and held other important positions. In the year 1872 he accepted the position of mining captain at the Norway mine, Norway, Mich. The following year, on account of a change of management, he resigned and accepted a similar position with the Lumbermen's Mining Co., and was mining captain of the Ludington and Stephenson mines of the above company. He was next induced to take charge of the operations at the Curry mine and remained there until influenced by the late Jeff Day, then superintendent of the Metropolitan Iron & Land Co., resigned and accepted a position under him at the Metropolitan mine on the Felch Mountain range which position he held until operations were practically suspended. In the spring of the year of 1885 he went to the Gogebic range and took charge of the mining operations which developed the Norrie, East Norrie and Pabst mines of the last named company and continued in the employ of this company until it sold its interests to the Oliver Iron Mining Co. Many important mining positions in different parts of the country were offered the captain after this but he could not be induced to accept any of them, he having made up his mind to retire from active mining pursuits. He returned to England in the year 1900 where, a year or two later, he met with an accident which developed a complication of diseases to which he succumbed Oct. 15th, 1905.

FRANCIS W. ANTHONY.

Born at Stockton, Mass., May 2nd, 1827. Came to lower peninsula in 1845 and to upper peninsula in 1847. Located at

Ontonagon river. Was superintendent of surface at the Michigan mine for a time, and subsequently built a military road for the United States government from Green Bay to Copper Harbor, receiving land grant for same. In 1882 settled on a farm about a mile from Hancock, Mich., and died there March 29th, 1908.

GIDEON TREVARTHEN.

Born in Cornwall, England, 1859. Came to America in 1869, settled in Humboldt, Marquette county, attended public school there and worked in the old Edwards mine as a miner, from there went to the Champion mine, and following the same occupation, from there went to Florence, Wis., and worked in the foundry then run by the Marinette Foundry & Machinery Co. Then served his time at the machinists trade, from there went with the Florence Mining Co. as master machinist. He remained with them until 1896, when he met with an accident in removing some machinery, and from the effects of the same he died, leaving a wife and three children, one son and two daughters. His son is now with the Tennessee Coal & Iron Co., as mining engineer, at Birmingham, Ala.

DANIEL D. BROCKWAY.

Born at Morristown, Vt., May 2nd, 1815. In childhood he moved to Malone, N. Y. He moved when a child to lower Michigan and as far west as Chicago, finally settling in Washtenaw county, Mich., in 1831. He was married at Galesburgh, Mich., Jan. 21st, 1836, to Miss Lucena Harris and then returned to Malone, N. Y., with his bride. His brother, W. H. Brockway later secured him the position of mechanic in the Indian reservation at Keweenaw bay, which position he at once accepted and started for the northern peninsula April 14th, 1843. From the Soo Portage they took the brig "John Jacob Astor" on August 4th, arriving August 8th, 1843, at L'Anse mission. Their first mail was received eleven months later by the schooner Chippewa. Mr. Brockway remained for three years at Keweenaw and leaving the Indian mission left by canoes with his wife and three daughters for Copper Harbor, arriving there May 3rd, 1846. During Mr. Brockway's stay at Keweenaw, a daughter was born and given the name of Sally, (now Mrs. S. L. Scott of Lake Linden), who was the first white child to be born and reared on Lake Superior. Two other children born on the Indian reservation died or left the country at an early age. Mr. Brockway immediately settled permanently on Copper Harbor and opened an hotel at which place almost all of the early explorers and settlers stopped and by whom he was well known. In 1849 he was placed in charge of the old North West mine, later the Delaware. In 1851 he forsook a small salary and returned to the hotel, and was appointed postmaster of Copper Harbor the same year. In 1863 he sold his boarding house and erected a private dwelling for his own use, doing some prospecting on his own account until 1858 when he went to the Isle Royal mine on construction work. In 1859 he was appointed state road commissioner by Governor Wisner, and was reappointed in 1861 by Governor Blair, commissioner for Mineral Range state road. In 1862 he moved his family into the Phœnix hotel at Eagle River and contracted for the hauling of copper and supplies from the Cliff mine. In 1863 he returned to Copper Harbor and entered the mercantile business for about three years. In 1867 he returned to the Harris, near Kalamazoo, in an attempt to retrieve his fortunes. Not meeting with success he returned in 1872 to the Cliff mine and again engaged in the mercantile business with his son Albert. In 1878 he bought a controlling interest in the Atlas mine and operated it in company with others. In 1879 with John Senter, Capt. Dick Uren, and Wm. and John Edwards, he made a trip to the Black Hills and acquired the Bismarck and Fairview claims, suffering a great deal of hardship on account of meeting with a severe blizzard. On the death of O. A. Farwell in 1881, he was appointed agent of the Cliff mine and remained as such until its sale to the Tamarack company in 1892. In 1895 Mr. Brockway bought a home at Lake

Linden and retired from active life, after 50 years of activity in the Lake Superior region. His wife died on March 2nd, 1899, and blind and helpless he followed her on May 9th, the same year. Thus for 56 years, Mr. Brockway had been almost a continuous resident of the northern peninsula and had done much towards its development in many ways. His hospitality was well known by almost all of the early men on the peninsula.

WILLIAM A. BURT.

Born in Worcester county, Mass., June 13th, 1792. Moved to New York in 1792. With but little education he mastered surveying, as then known. Moved to Erie county, New York in 1809. Served in the war of 1812. In 1813 married Phoebe Cole. Came west in 1817 to St. Louis, and to Auburn, Michigan in 1822. In 1833 he was appointed United States deputy surveyor, and commenced work in lower peninsula. In 1835 he invented the solar compass. In 1844 he discovered iron ore in town 47-27 West in E. line. In this party were Jacob Houghton, Wm. Ives, H. Mellen, R. S. Mellen, James King and two Indians named John Taylor and Michael Doner. Mr. Burt was a man of high inventive faculties and almost completed his equatorial sextant previous to his death on August 18th, 1858. His discovery of the iron bearing formation was really the beginning of the iron ore mining in the upper peninsula.

WILLIAM EDMUND DICKINSON.

Born in New York city, May 31st, 1824. Admitted to bar of state of Connecticut in 1844, and practiced law until 1846. For the next three years, he sailed on a whaling vessel, returning in 1849, at which time he married Delia E. Welch, of Litchfield, Conn. Owing to his wife's ill health, he decided to locate in the northern peninsula of Michigan. He located at Ontonagon, and had charge of the Bohemian and other mines in that county, and in Houghton until 1865. During this time his wife died. In 1865, he moved to Rockey Bar, near Boise City, Idaho, to develop a gold and silver claim for Jos. Hanna and others. In 1867, he returned to New York and married Elizabeth S. G. Sargent, of Boston, Mass. In 1870, he returned to Lake Superior and took charge of the New York mine at Ishpeming, Michigan, for Samuel J. Tilden and others. In 1881, he moved to Commonwealth, Wis., and was superintendent of the Comomnwealth mine for Tuttle Bros., until 1889, at which time he moved to Bessemer, Mich., to take charge of the Colby mine for Charles Colby. In 1892-3 he went to Daquire, Cuba, to develop the Spanish American mines near Santiago, for the Colbys, under Mr. S. P. Ely. He left this place on account of the unsettled conditions of the government and returned to the United States in 1896, settling in Florence county, Wis. From that time until his death, June 15th, 1899, he was general agent for the Aetna Powder Co. Mr. Dickinsón's connection with the mining industry was long and varied, and he won the esteem and affection of all who were brought in contact with him, by his many sterling traits of character.

JEFFERSON D. DAY.

Born in Chatauqua county, New York, March 15th, 1840, and died at South Lake Linden, Houghton county, Michigan, December 5th, 1895. He came to the copper country of Michigan in 1864, being employed as a surface foreman at the mines in the vicinity of Hancock for two years, followed by two years' service at the Calumet & Hecla mine. In 1868 he went to Marquette county, and for eleven years held positions of trust and responsibility with the Lake Superior Iron company, resigning the position of assistant superintendent in 1879 to go with the Menominee Mining company as assistant superintendent for Dr. Hulst. Mr. Day became identified with the Metropolitan Iron & Land Co. in 1882, when the company was operating at Felch mountain, in what is now Dickinson county, Michigan, and remained with that company until his death.

In 1885 he was appointed superintendent, and when the company transferred its operation to the Gogebic range he was appointed general superintendent of its extensive interests at Ironwood, which included the Norrie, East Norrie and Pabst mines. His connection with Ironwood dated from the beginning of the town and he was prominently identified with the movements which resulted in the creation of the county of Gogebic out of territory detached from Ontonagon county and the incorporating of the village and finally city of Ironwood. Mr. Day was married to Miss Jennie Hague at Hancock, Mich., in 1868, whose father, Thomas Hague, was one of the early pioneers of that place. An interesting occurrence in his life was his driving with Capt. Nat Moore from Ashland, Wis., to the exploration, now the Colby mine, in the spring of 1884 or 1885. On his recommendation Mr. Chas. L. Colby began the development of the mine.

JOHN DUNCAN.

Born in Argyleshier, Scotland, in 1835, and came with his parents to Canada in 1842, at the age of 7. Learning the carpenter trade, he was employed on railway construction work in southern Michigan up to the age of 23, when on account of contracting malaria, he moved to the northern peninsula. He obtained employment first at the Quincy mine in 1859, as carpenter foreman, then as surface captain, and worked as such for nine years. He then went as surface captain and assistant superintendent to the Calumet & Hecla mine in 1868, in charge of all surface work and also of all lands owned by the company, which position he held until his death, June 5th, 1904. Mr. Duncan was one of the best known men in the Lake Superior region. His charity, patriotism and unselfishness won him the esteem of all who knew him, and made him one of the prominent figures in the upper peninsula for years. He was an active worker in fraternal societies and an ardent republican in politics. His prominence as a mining man won him the presidency of the Mining Institute in 1895.

PETER WHITE.

Born at Rome, N. Y., October 31st, 1829. His family moved to Green Bay, Wis., in 1841, and he ran away from home in 1842 at the age of 13, going to the Island of Mackinaw. Here he worked for two years for Edward Kanter, a storekeepeer, and also on vessels coming into Mackinaw. On one occasion he fell, breaking his arm badly while unloading a boat at Bay City, Mich. In 1844 he was employed by Capt. Augustus Canfield as timekeeper on the government work constructing Waugoshance lighthouse. In 1849 he went, with Robert J. Graveraet to the present site of Marquette, and felled the first tree when the first clearing was done. In 1850 he was in charge of the store for the Marquette Iron Co., and in the winter of 1850 and 51, he carried the mail to L'Anse, making nine trips on snow shoes. In 1852 he was appointed postmaster of Carp River, it being the first postoffice of Marquette, and which was afterwards changed to Marquette, holding the office until 1864. In July, 1852, he wrote the first bill of lading for six barrels of iron ore, the first shipment of ore made from the northern peninsula. During the year 1855 he was placed in charge of the management of the lands of the Marquette Iron Co., and from that beginning he became interested in the real estate business and remained more or less interested until his death. In 1856 he was elected to the state legislature, and walked most of the way to Lansing to attend the session. He was appointed collector of customs and also studied law, and was admitted to the bar in 1857. In 1857 Mr. White married Miss Ellen S. Hewitt of Marquette. He also named the town of Ishpeming. He had been interested in a private banking enterprise which in 1862 he incorporated into the First National bank of Marquette, Samuel P. Ely, of Marquette, being elected president and he cashier. In 1872 he built at his expense the public library of Marquette and dedicated it to the city. He was elected in 1875 to the state senate. He also secured the passage of the measure in congress that gave to Marquette the beautiful public park at Presque Isle. In 1900 the University of Michigan conferred the degree of LLD. upon him, and in 1902 the same institution made him one of its regents. In 1904 a new library building was erected in Marquette and named after him. He died June 7th, 1908. The history of the iron ore industry of the Lake Superior region is written in his biography, "The Honorable Peter White" and he stands as the foremost character developed in the northern peninsula of Michigan.

PHILO MARSHALL EVERETT.

Born in Winchester, Conn., October 21st, 1807. When a young man he moved to New York state and lived for a number of years in Ulster and Oneida counties. He was married in Utica, N. Y., and lived for a time afterward in Kingston. During the time he lived in New York he had a contract for making cement for the original Croton water works project, and later had a contract for the construction of a section of the Erie canal. In 1840 he moved to Michigan and with his wife and one child drove from the then end of the Michigan Central railroad at Ann Arbor to Jackson, Michigan, where he settled. He lived at Jackson, Michigan, until about 1845, conducting a mercantile and wheat commission business. As was the case with most of the early settlers in Michigan, he suffered a great deal with ague and chills and fever, which very seriously affected his general health and resulted in a long fit of sickness which affected his eyesight to such an extent that for about a year he was totally blind. He finally recovered his eyesight, however, so that he could get about and do ordinary business, but for the balance of his life his eyesight was very poor. In 1845 he and his brother-in-law, Charles Johnson, were both in poor health and their physician advised them to go to the upper peninsula. At this time the village of Copper Harbor was attracting much attention as a great mining town and wonderful stories were told of the richness of the country. They finally concluded to go to this place. While at Sault Ste. Marie looking for guides and boats to proceed up the lake, he met an old squaw, a member of the Chippewa or Ojibway tribe, who told them of a rock or mineral, which was too hard for the Indians to use, but which she thought the white men, with their wider experience, might make use of. She described the place where to look for the rock, which was near the Carp river, which empties near the city of Marquette, and gave them the directions and distance from the mouth of the river they should go, to a place where they would find some pieces of copper buried under the leaves at the foot of a large pine tree, and near this pine tree they would find the hard rock. They finally got their guides and boats and coasted up the shore in a so-called mackinac boat. On reaching Marquette they found that the spot described by the old squaw was on the hunting ground of Marji Gezicks, who happened to be then at L'Anse for the payment of the government bounty or assistance which was given to the Indians. After a few days he returned and they got his permission to go to the place. They had no trouble in finding the place and found it just as the old squaw had described it. Near the foot of this pine tree was a boulder of jasper and iron, and this was the discovery upon which was made the location of the Jackson Iron company. This old pine tree stood for many years until the company found it necessary to mine under and around it, when it was cut down. The stump remained there for many years, but within the last five or ten years has been destroyed by fire. After Mr. Everett found this he concluded that it was better than to go further to look for copper, so went back to the land office at Sault Ste. Marie and made a mineral location of the land. The point where this discovery was made is about the center of section 1-47-27. This entire section was located and finally a mineral lease was secured of this land, and later when the land was opened for entry this section 1 was purchased for the benefit of the Jackson Iron company. After this discovery Mr. Everett returned to Jackson and interested sufficient of the prominent business men then there to form a company of thirteen members. He returned to the upper peninsula the next year with some men to open up the deposit and finally built a bloom forge on the Carp river just below Negaunee, which was operated a few years, and it was at this point that the first iron manufactured in the upper peninsula of Michigan was made. He returned in 1846 and 1847, and again in 1848 and 1849, and finally moved to what is now the city of Marquette with his family in the fall of 1850. Test cargoes of this iron were sent to Sharon, Pennsylvania, and also to Pittsburgh, where it was found to be of a very valuable character. The original boulder of jasper and iron is now in the Smithsonian Institute in Washington and was sent there by Mr. Everett. He was the first and only supervisor of Marquette county originally elected, and was also the first judge of probate. He and his wife were members of St. Paul's Episcopal church of Jackson, and when they settled here were very anxious to start a church, but as they and one other were the only communicants, it was not until 1855 that they could get a church started. They worked hard and constantly, and in 1856 the first Episcopal church building was put up and was called St. Paul's. From the institution of the church for many years he was senior warden, and from the time when he was unable to actively fulfill the duties of this office until the time of his death was senior warden emeritus of the church. He died September 15, 1892, at Marquette, Michigan, at about the age of eighty-five years.

PAST OFFICERS.

PRESIDENTS.

Nelson P. Hulst	1893
J. Parke Channing	1894
John Duncan	1895
William G. Mather	1896
William Kelly	1898
Graham Pope	1900
W. J. Olcott	1901
Walter Fitch	1902
George H. Abeel	1903
O. C. Davidson	1904
James MacNaughton	1905
Thomas F. Cole	1906

(No meetings were held in 1897, 1899 and 1907.)

VICE-PRESIDENTS.

1893.

John T. Jones.		Graham Pope.
F. P. Mills.	J. Parke Channing.	M. W. Burt.

1894.

John T. Jones.		Graham Pope.
F. P. Mills.	R. A. Parker.	W. J. Olcott.

1895.

F. McM. Stanton.		Per Larsson.
Geo. A. Newett.	R. A. Parker.	W. J. Olcott.

1896.

F. McM. Stanton.		Per Larsson.
Geo. A. Newett.	J. F. Armstrong.	Geo. H. Abeel.

1898.

E. F. Brown.		Walter Fitch.
James B. Cooper	Ed. Ball.	Geo. H. Abeel.

1900.

O. C. Davidson.		J. H. McLean.
T. F. Cole.	M. M. Duncan.	F. W. Denton.

1901.

J. H. McLean.		F. W. Denton.
M. M. Duncan.	Nelson P. Hulst.	William Kelly

1902.

William Kelly.		H. F. Ellard.
Nelson P. Hulst	Fred Smith.	Wm. H. Johnston.

	1903.	
H. F. Ellard. Fred Smith.	James B. Cooper.	Wm. H. Johnston. John H. McLean.
	1904.	
M. M. Duncan. Fred M. Prescott.	F. W. McNair.	John H. McLean. James B. Cooper.
	1905.	
M. M. Duncan. Fred M. Prescott.	F. W. McNair.	J. M. Longyear. F. W. Denton.
	1906.	
M. M. Duncan. J. M. Longyear.	Fred M. Prescott.	F. W. McNair. F. W. Denton.

MANAGERS.

	1893.	
John Duncan. Walter Fitch.	William Kelly.	James MacNaughton. Charles Munger.
	1894.	
Walter Fitch. John Duncan.	M. E. Wadsworth.	C. M. Boss. O. C. Davidson.
	1895.	
F. P. Mills. Ed. Ball.	M. E. Wadsworth.	C. M. Boss. O. C. Davidson.
	1896.	
F. P. Mills. Ed. Ball.	C. H. Munger.	Graham Pope. William Kelly.
	1898.	
M. M. Duncan. J. D. Gilchrist.	T. F. Cole.	Graham Pope. O. C. Davidson.
	1900.	
E. F. Brown. Ed. Ball.	James B. Cooper.	Walter Fitch. George H. Abeel.
	1901.	
James B. Cooper. James MacNaughton.	(One Vacancy.)	James Clancey J. L. Greatsinger.
	1902.	
James Clancey. J. L. Greatsinger.	Amos Shephard.	Graham Pope. T. F. Cole.
	1903.	
Graham Pope. Amos Shephard.	Wm. J. Richards.	T. F. Cole. John McDowell.
	1904.	
John McDowell. Wm J. Richards.	John C. Greenway.	William Kelly. H. B. Sturtevant.
	1905.	
John C. Greenway. H. B. Sturtevant.	Felix A. Vogel.	William Kelly. J. R. Thompson.
	1906.	
John C. Greenway. Jas. R. Thompson.	William Kelly.	H. B. Sturtevant. Felix A. Vogel.

TREASURERS.

C. M. Boss	1893
A. C. Lane	1894
Geo. D. Swift	1895-1896
A. J. Yungbluth	1898-1900
Geo. H. Abeel	1901-1902
E. W. Hopkins	1903-....

SECRETARIES.

F. W. Denton	1893-1896
F. W. Denton and F. W. Sperr	1898
F. W. Sperr	1900
A. J. Yungbluth	1901-....

LIST OF PUBLICATIONS RECEIVED BY THE INSTITUTE.

American Institute of Mining Engineers, 99 John St., New York City.

Canadian Mining Institute, Ottawa.

American Society of Civil Engineers, 220 W. 57th St., New York City.

Institution of Mining Engineers, Neville Hall, Newcastle-upon-Tyne.

Massachusetts Institute of Technology, Boston, Mass.

Chemical, Metallurgical and Mining Society of South Africa, Johannesburg, S. A.

Western Society of Engineers, 1734-41 Monadnock, Blk., Chicago.

The Mining Society of Nova Scotia, Halifax, N. S.

Canadian Society of Civil Engineers, Montreal.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

State Bureau of Mines, Colorado, Denver, Colo.

Stahl and Eisen, Dusseldorf, Germany, Jacobistrasse 5.

Reports of the U. S. Geological Survey, Washington, D. C.

Geological Survey of New South Wales, Sydney, N. S. W.

Geological Survey of Ohio State University, Columbus, O.

The Mexican Mining Journal, Mexico City, Mexico.

Mines and Mining, 1824 Curtis St., Denver, Colo.

Engineering-Contracting, 355 Dearborn St., Chicago, Ills.

LAKE SUPERIOR IRON ORE SHIPMENTS FROM THE DIFFERENT RANGES FOR 1904, 1905, 1906 AND 1907, AND GRAND TOTAL, FROM 1855 TO 1907, INCLUSIVE:

(Compiled from tonnage as published by Iron Trade Review.)

		1904	1905	1906	1907	Grand Total.
Marquette Range	(Tons	2,843,703	4,210,522	4,057,187	4,388,073	85,245,874
	(Per ct.	13.	12.2	10.5	10.3	22.41
Menominee Range	(Tons	3,074,848	4,495,451	5,109,088	4,964,728	63,641,213
	(Per ct.	14.1	13.1	13.3	11.8	16.71
Vermilion Range	(Tons	1,282,513	1,677,186	1,792,355	1,685,267	26,785,426
	(Per ct.	5.9	4.9	4.7	4.	7.04
Gogebic Range	(Tons	2,398,287	3,705,207	3,641,985	3,637,907	54,107,342
	(Per ct.	11.	10.8	9.4	8.6	14.2
Mesabi Range	(Tons	12,156,007	20,153,699	23,792,882	27,492,949	150,235,558
	(Per ct.	55.7	58.7	61.7	65.1	39.5
Miscellaneous	(Tons	67,480	111,391	128,742	76,146	*401,672
	(Per ct.	.3	.3	.4	.2	.14
	Total tons	21,822,839	34,353,456	38,522,239	42,245,070	380,417,085
		Decrease from 1903 10.2 p.c.	Increase over 1904 57.4 p.c.	Increase over 1905 12.1 p.c.	Increase over 1906 9.8 p.c.	

*Iron Ridge, Wisconsin....Tons....143,039
Illinois, Wisconsin ....Tons....258,633

Tons....401,672

Increase for 1907 over 1902, 53 p. c.